IMPROVING SOIL FERTILITY THROUGH ORGANIC RECYCLING

FAO/UNDP REGIONAL PROJECT RAS/75/004

Project Field Document No. 14

MINERAL OR ORGANIC ?

FOOD AND AGRICULTURE ORGANIZATION

OF THE UNITED NATIONS

IMPROVING SOIL FERTILITY THROUGH ORGANIC RECYCLING

(FAO/UNDP Regional Project RAS/75/004)

THE COMPARATIVE EFFECTS UPON SOIL FERTILITY OF MINERAL FERTILIZERS AND ORGANIC MANURES WHEN USED SEPARATELY AND TOGETHER

(A compilation and evaluation of experimental findings in Asia)

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

PREFACE

Organic manures which were once the only source of plant nutrient supply, became neglected with the advent of easily available mineral fertilizers. The recent world energy crisis has made it necessary to search for alternative and renewable resources of nutrients and this has aroused interest again in organic manures.

For sustaining high yielding agriculture, the continued and even increased, use of mineral fertilizers is essential. However, it has been realised that for optimum productivity a balanced, rational use of mineral fertilizers together with organic manures is necessary. The use of organic manures not only increases the efficiency of mineral fertilizers but maintains and improves the physical and microbiological conditions of a soil.

Among agriculturists there are extremists on both sides: those who deplore the use of any mineral or 'chemical' fertilizers at all and, those who deride the use of bulky, unmanageable, 'old-fashioned' manures. As in most matters the answer lies in a compromise, utilizing both kinds of material for maximum benefit.

Many experiments have been made to compare the effects of mineral fertilizers with those of organic manures - particularly in countries of the West - and such investigations are, of necessity, long term affairs. In Asia too, a considerable amount of experimentation has been made but the results are either scattered in the literature, lost in government or institute files or unrecorded.

This publication is an attempt to bring together the results of such work in Asia. However, a mere compilation of experimental results involving as they do, many different kinds of soil, crop, fertilizer, manure and management practices, is of limited use. The compilation is an essential documentation with potential value of facts and findings that will be available for reference but it was felt that some sort of evaluation should be attempted having as its logical end point some guidelines for the farmers.

The document is divided into three main sections. Part I contains the practical aspect of the study; the overall, general conclusions and interpretation of results. It is intended particularly for assisting extension workers in advising farmers but may also be of use to those engaged in the teaching and planning of agriculture in Asia. Part II, from which Part I was derived, is a more scientific, detailed interpretation of results and is also intended mainly for extension workers. Part III is the literature survey itself, of necessity condensed but fully documented. It is realised that the review must be incomplete, much more information is surely available

if it could be traced, but it is at least a beginning and helps to make more quantitative the axiom that the complementary use of mineral fertilizers and organic manures is a desirable agricultural practice.

It is conceded that the evaluation of results presented in Part II, even with the simplified interpretation as in Part I, does not fulfill the requirements of a practical Handbook. Furthermore, unlike mineral fertilizers which have exact, precise formulations, organic manures are extremely variable in nature and composition. It is feasible that animal dung may vary in composition over even short periods of time and that farmyard manure produced in one location differs from that in another. Thus, at present, no hard and fast rules can be made for utilization of organic manures.

As an attempt to improve the practices of manuring, it is the intention of the regional project to produce a publication giving the comparative analyses of organic manures - in so far as the necessary information can be found. This information together with the results of on-going research into the methodology of organic manuring, with the findings presented here on complementary use of mineral fertilizers and with a discussion of the relevant economics should lead to a Handbook giving specific advice and guidelines for agricultural extension workers.

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CONTENTS

PART I

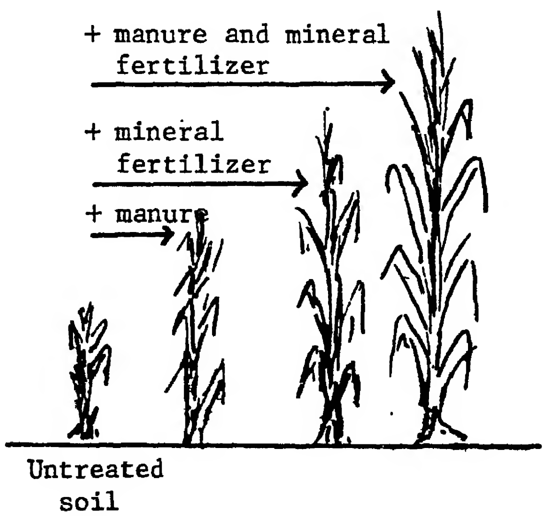
MINERAL OR ORGANIC ?

This section of the Handbook, although presented first, is a simplified, summarized series of conclusions formed from an analysis of a literature survey (Part III) and its interpretation (Part II).

Due to isolated and sometimes contradictory reports or experiences, many farmers are confused over the relative merits of mineral fertilizers and organic manures. It is intended that this short section of the Handbook should remove the confusion and help the farmer, either directly or after further simplification via an agricultural extension worker, to select and use the most appropriate fertilizer/manurial practice for his land.

We can commence with the overall conclusion that:

WHEREAS MINERAL FERTILIZERS AND ORGANIC MANURES BOTH SEPARATELY HAVE BENEFICIAL EFFECTS UPON SOILS AND CROPS, THE MOST POSITIVE AND REWARDING RESULTS COME FROM A COMBINED USE OF THE MATERIALS.



Mineral fertilizers are nowadays formulated very precisely and specifically, the farmer knows exactly what he is applying as plant nutrients to the soil. And as recommendations for mineral fertilization are generally based on field trials, the farmer can often forsee the possible yield increase. Mineral fertilizer application is a well established science.

Such precision regarding nutrient supply does not exist for organic manures. There are very many different kinds of manure; they vary in texture, nutrient content, moisture and ability to decompose; even the same manure will changes in composition with time.

Although some data exist on the chemical composition of some manures, no systematic investigation has been made and manuring remains an art rather than a science. And it is likely to remain so for a long time as standardization of the many kinds of organic manures is almost impossible.

As a result, different kinds of organic manures will give different effects or degrees of effect, upon soil conditions and crop yield. The precise effects can be found only by experience but the overall, general effects of all kinds of manures can be forseen and are summarized here.

For increased or sustained crop yields, a farmer must use mineral fertilizers However, if he continuously uses only mineral fertilizers without any return of organic matter to the soil, his land and crops will eventually suffer.

If mineral fertilizers are unavailable for any reason, then farming can be improved by use of organic manures. If only manures and no fertilizers are used the land will benefit but yields will be relatively low.

Plant growth and crop yields are governed by a number of factors. Optimum soil and water conditions and an adequate supply of nutrients are the basic requirements.

Ideal soil conditions permit good root growth thus enabling the plants to extract nutrients from a large soil volume. A strong root system also reduces the susceptibility of plants to lodging and drought.

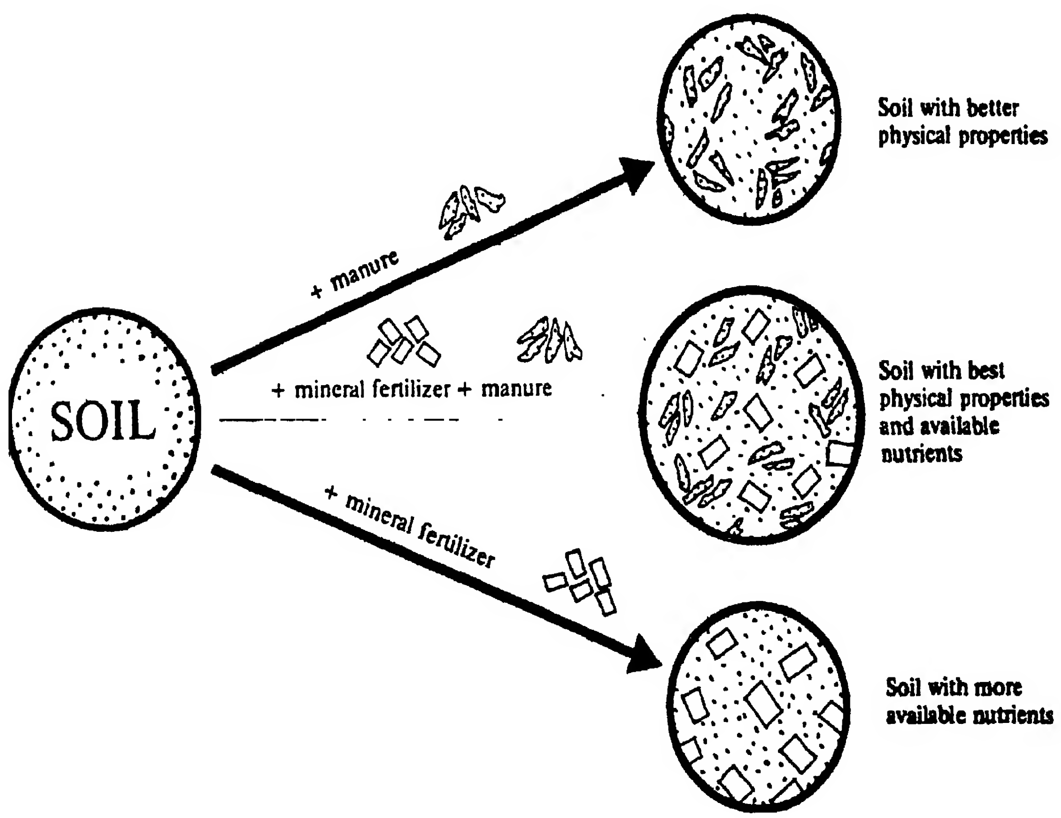
Nutrient availability to plants is governed by soil fertility status and the physico-chemical conditions which govern biochemical reactions in a soil. Plant nutrients undergo a number of complex reactions in soil depending upon the physico-chemical and microbiological conditions. Optimum physico-chemical and biological conditions ensure a good availability of plant nutrients.

An intensive cropping system requires replenishment of plant nutrients. Fertilizers provide readily available plant nutrients in a concentrated form and generally, they do not have any significant effect on the physical properties of soil. Organic manures are low in nutrients but play a vital role in improvement of physical, physico-chemical and biological soil properties. Availability of nutrients from them is slow but long lasting.

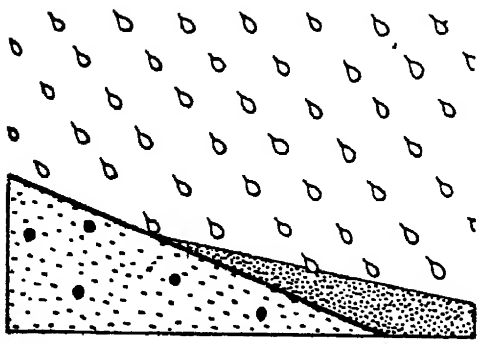
Mineral fertilizers and organic manures have favourable effects upon most chemical, physical and microbiological soil properties when used separately. However, with the exception of phosphatic fertilizers, continuous use of mineral fertilizers alone may have adverse effects upon soil structure and related

properties if the organic matter content is low. Organic manures improve soil structure.

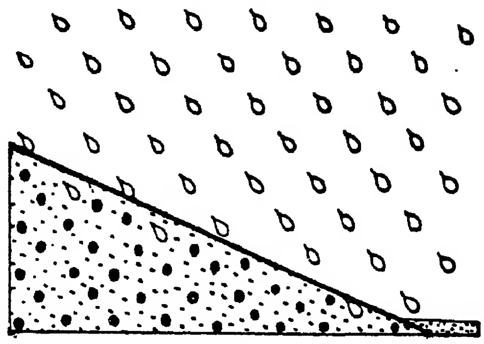
Thus use of organic manures alone will result in a soil with improved physical and microbiological properties, use of mineral fertilizers alone will increase the quantity of available plant nutrients and the use of both together will give a soil rich in nutrients and with physical and microbiological properties that will increase the availability of those nutrients and maintain good tilth.



For example, addition of manure to soils having poor drainage will improve water infiltration and check erosion losses. Use of fertilizer alone does not result in any such effects.



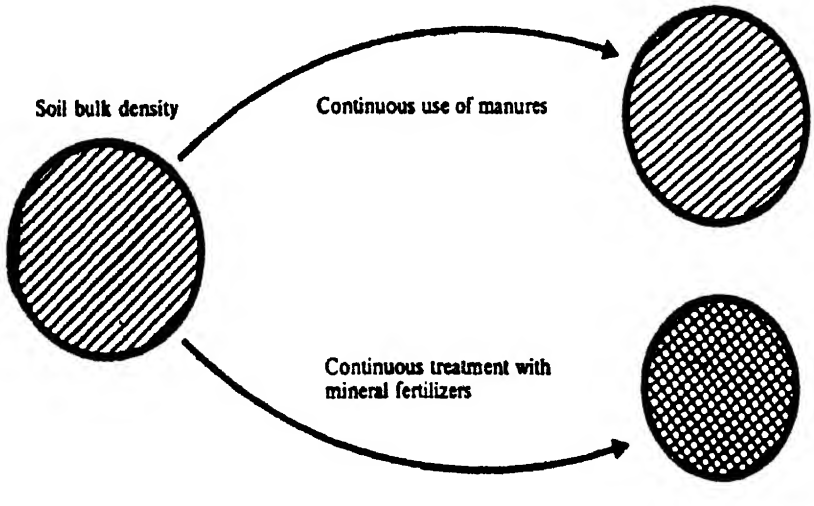
In soils with little organic matter erosion is severe. Soil along with nutrients is lost.



In soils with organic matter impact of rain is reduced. Water seeps gently. Surface runoff and erosion are reduced.

The degree of compactness of a soil can be measured by its bulk density and this property has important effects upon plant growth. If a soil has too low a density (e.g. a loose, sandy soil) it tends to have a low water holding capacity and high leaching rate. If the density is too high, air space and water holding pores are restricted and physical opposition is given to root growth.

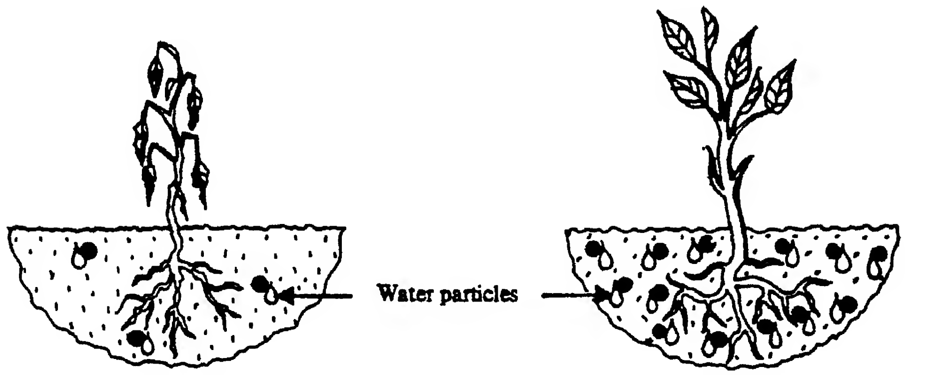
It has been found that continued use of only mineral fertilizers tends to increase the bulk density of soils; organic manures however, have hardly any lasting effect.



No change in bulk density

Increase in bulk density (except where increased growth results in more crop residues)

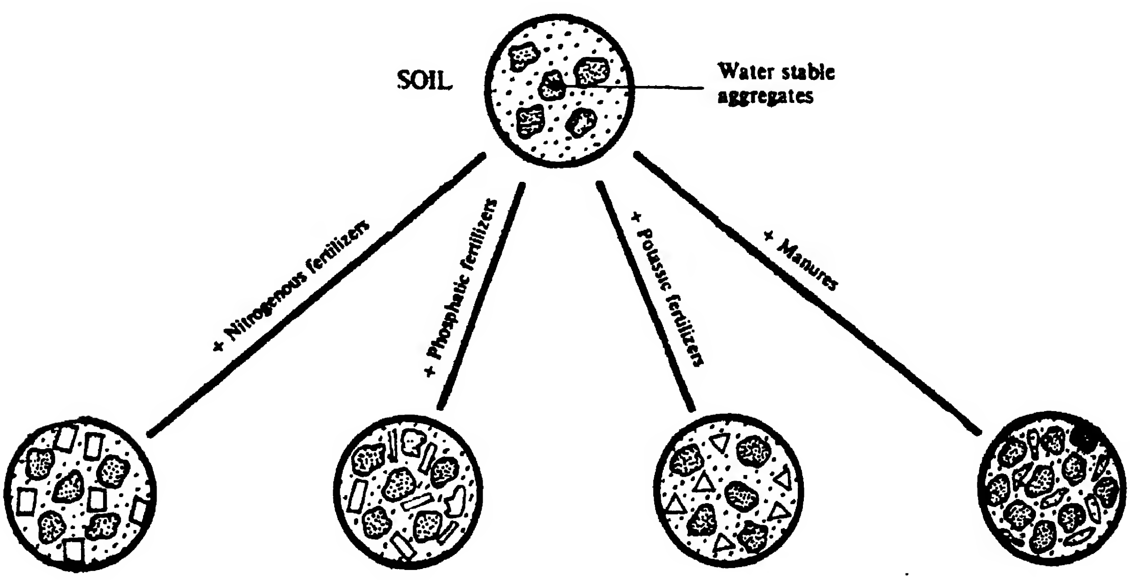
If a soil has little clay and little organic matter, it usually can not hold sufficient water for good plant growth and will need frequent irrigation. This defect can be remedied by adding manures to the soil as the organic materials can hold water; mineral fertilizers do not have this effect.



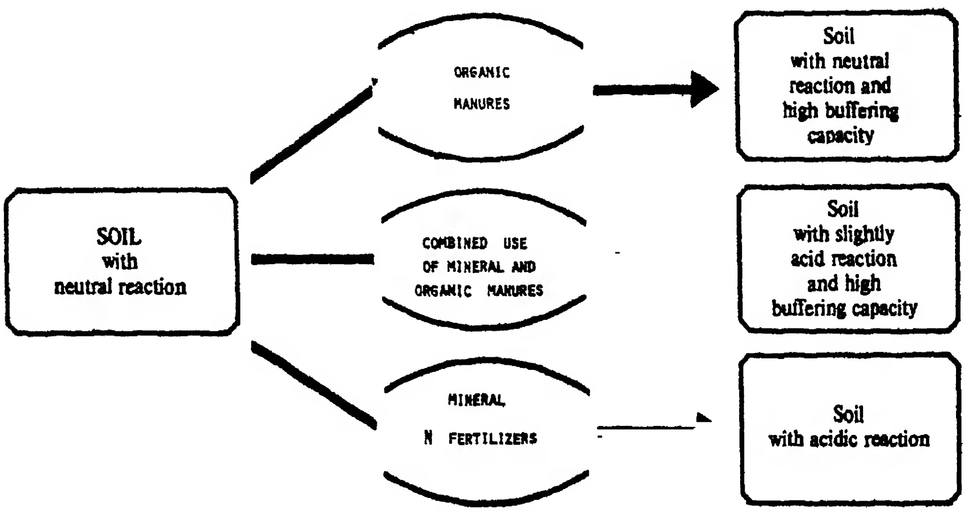
Water-retention power of soils with low organic matter is low. Plants grown in such soils are easily affected by drought.

Soils with adequate organic matter have good water-holding capacity. The organic matter retains moisture and thus helps in combatting drought.

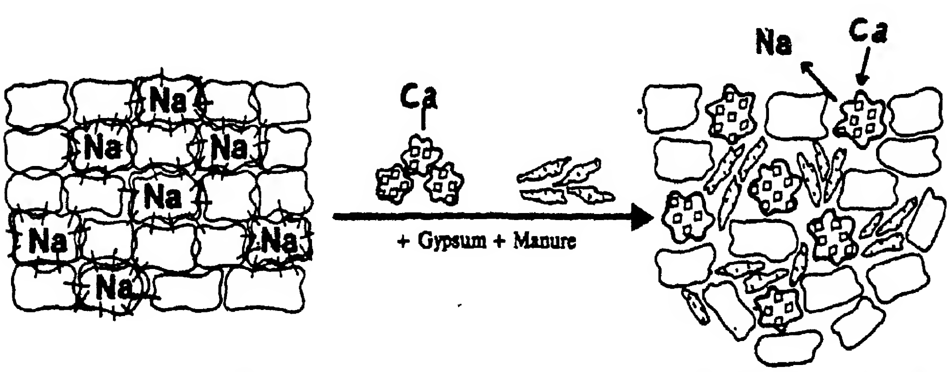
Another important characteristic of a soil is the percentage of aggregates (small crumbs formed by particles adhering to each other) which are stable when wetted. This property affects the structure of a soil and hence its tilth Application of manures results in an increase of water stable aggregates in soils. Phosphatic fertilizers too, favour the building up of aggregates but nitrogenous and potassic fertilizers do not have this effect.



Continuous use of some mineral fertilizers, for example ammonium sulphate, ammonium phosphate, urea and ammonium nitrate, can increase soil acidity. Use of fertilizers like sodium nitrate on the other hand, tends to make soil alkaline. Organic manure alone has no effect on soil reaction and, if used together with mineral fertilizers, it acts as a 'buffer' reducing or eliminating the effects of the fertilizer.



In the special case of alkali or 'sodic' soils, organic matter can help in their amendment. Usually gypsum is used to amend such soils when the calcium exchanges with the sodium that causes poor structure. Gypsum is still required to reclaim sodic soils but if organic matter is added also, the effect of the gypsum is enhanced.

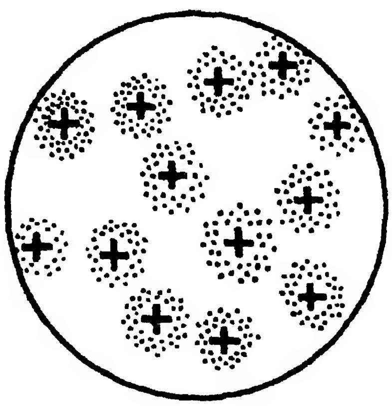


In alkali soils sodium ions hold the soil particles too close, structure is destroyed.

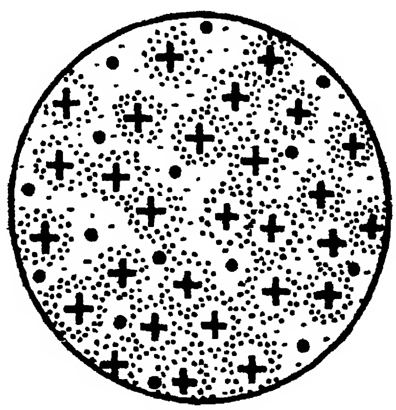
With the use of gypsum and manure soils are reclaimed – pH lowered and structure improved.

The ability of a soil to provide plant nutrients to the roots depends to a considerable extent upon its capacity to adsorb and hold those elements. This capacity is called the 'cation exchange capacity' and itself depends upon the content and nature of very fine particles (clay) and/or organic matter.

It has been found that mineral fertilizers and organic manures when used separately, can increase cation exchange capacity. However, as organic matter itself has the power to hold cations, the increase is more noticeable with manures than with fertilizers.



Many kinds of soil that do not receive additions of organic matter may have low cation exchange capacity. There are more chances of nutrient losses in such soils. (Some soils however, can have high exchange capacity even with low organic matter).

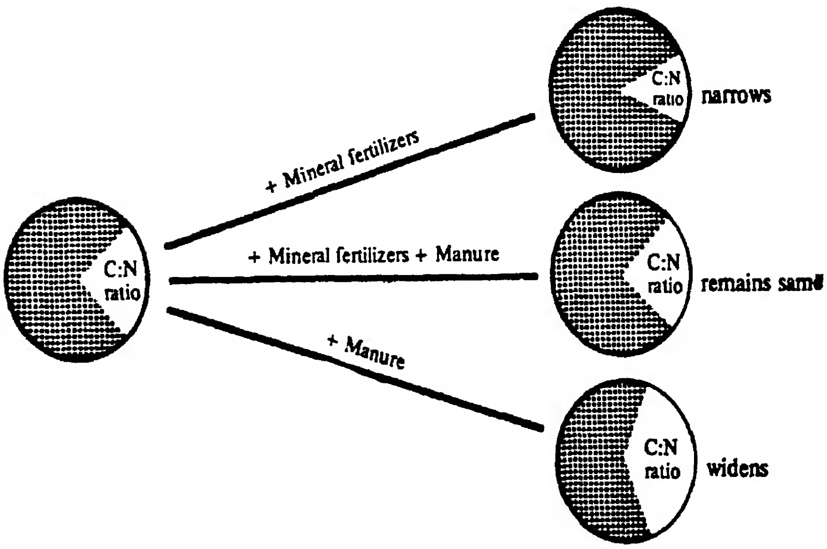


Soils with organic matter can have higher cation exchange capacity and retain the nutrients added in mineral fertilizers in available forms.

Long term application of organic manures may result in increase of organic carbon and humus content of a soil. However, rapid oxidation of soil organic matter due to high temperatures in many parts of the Asian continent does not permit spectacular build up. Mineral fertilizers have little effect upon organic carbon content except indirectly by increasing plant growth and hence organic residues in the soil.

Use of organic manures widens the C:N ratio; that is, the proportion of organic carbon to organic nitrogen in a soil and which governs the rate of decomposition of organic matter and hence release of plant nutrients. Mineral nitrogen fertilizers narrow the ratio and hasten the process of decomposition.

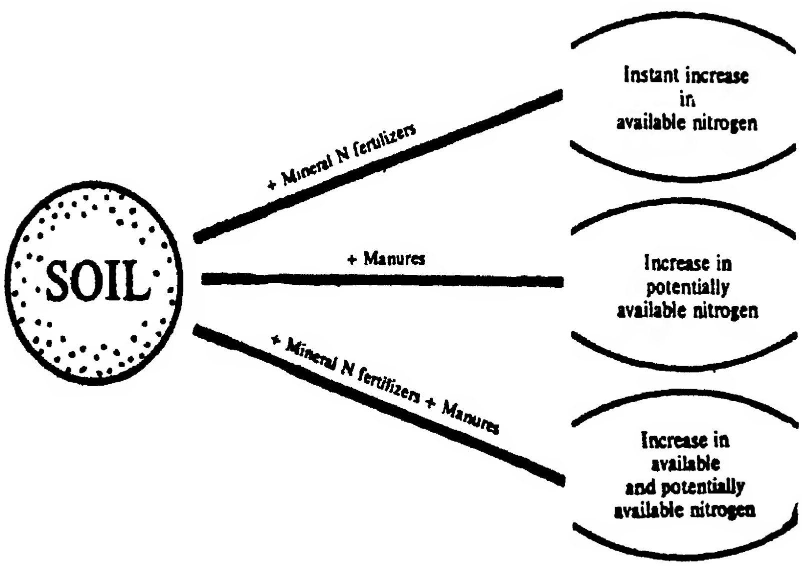
Thus if rapid decomposition of carbon-rich organic manures (e.g.straw) is required, mineral nitrogen fertilizers should also be added.



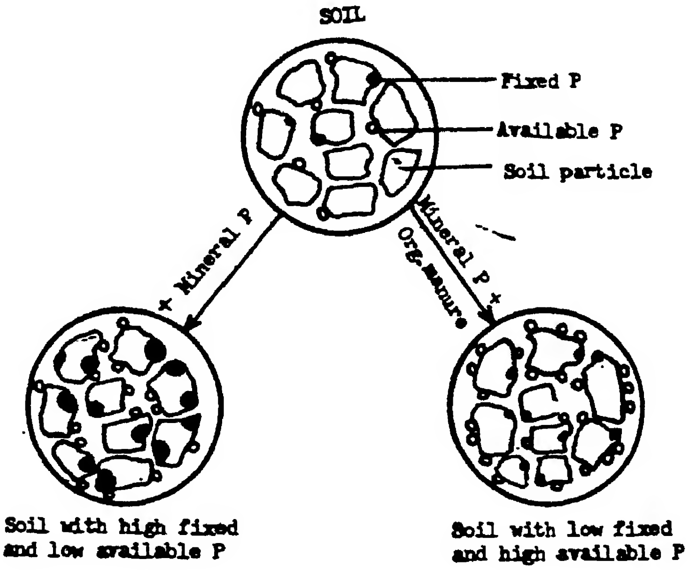
Soil organic matter decomposes more quickly.

Decomposition of soil organic matter retarded.

Addition of mineral nitrogen fertilizers to soil results in instant increase in available nitrogen. Manuring with organic materials on the other hand, increases the potentially available nitrogen which has longer lasting effects. In certain situations if manuring is done with organic materials having wide C:N ratios (for example crop stalks or straw), temporary immobilization of available nitrogen may result because the nitrogen is needed to break down the organic material. This problem may be resolved through simultaneous use of manure and mineral fertilizer.



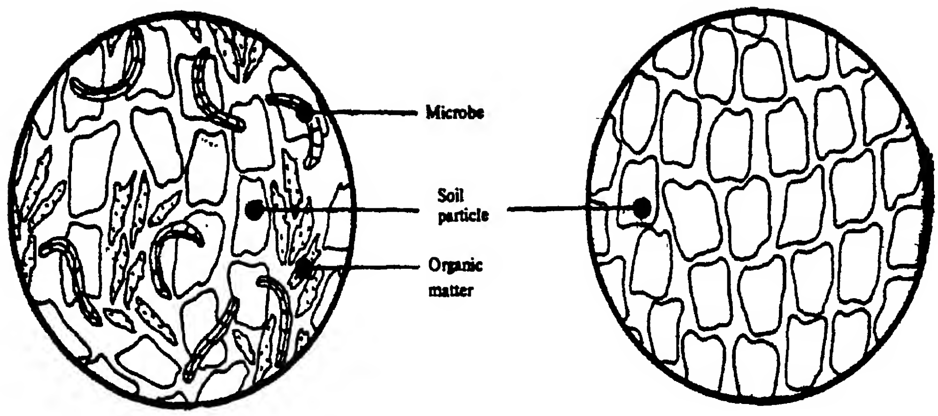
Mineral phosphatic fertilizers are the best source of available phosphorus for crops but in many soils the mineral phosphorus becomes quickly fixed and unavailable. In such cases complementary use of organic manures can result in higher phosphorus availability. Organic manures increase the availability of phosphorus not only through mineralization of the organically bound phosphorus but reducing fixation of added mineral phosphorus and by releasing phosphorus from complexes with acids formed during its decomposition.



Similarly, the effectiveness of mineral potassic fertilizers is enhanced in presence of organic manures. Available potassium usually increases with application of farmyard manure; mineral nitrogen fertilizers may result in less available potassium and so if both nutrients are needed both should be added.

High analysis fertilizers usually have low micronutrient content. Organic manures can be a good source of micronutrients and at the same time provide improved soil conditions for making the nutrients available to plants.

In general, organic manures promote biological activities in soils. This in turn normally results in better soil structure and increased availability of plant nutrients, whether these come from the manure or from added mineral fertilizers.

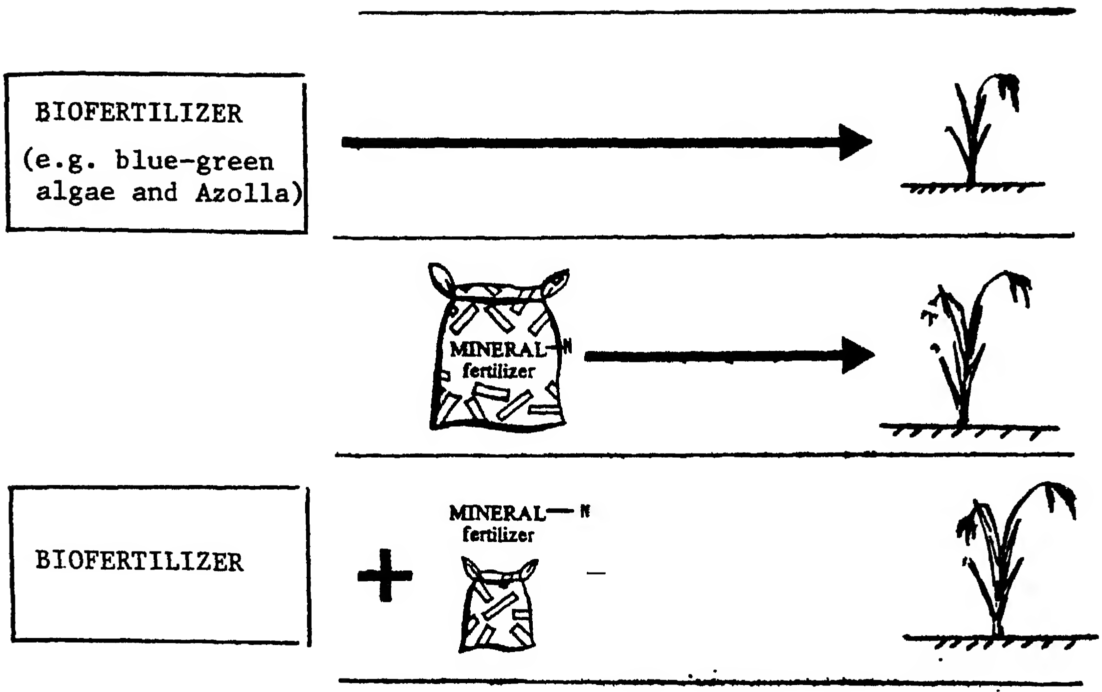


Soils with good quantities of organic matter favour microbial activity - vital for biochemical reactions.

Soils with little organic matter have little microbial activity.

In recent years much attention has been given to the use of so-called 'biofertilizers' to provide nitrogen to crops, particularly rice. Biofertilizers (for example Azolla and blue-green algae) have the ability to fix atmospheric nitrogen and, when the plant material is incorporated into the soil, this nitrogen is released in available inorganic form. However, although some exceptions have been reported, mineral nitrogen is also needed for best results.

The use of biofertilizers is really a special form of green manuring and, as might be expected, green manures together with mineral fertilizers are more effective than if used separately. The value of green manures is that aside from providing organic matter they reduce the quantity of mineral nitrogen that must be added.



The various investigations made in Asia have shown conclusively that optimum yields are obtained where mineral fertilizers are used in conjunction with organic manures. Complementary use results in better utilization of plant nutrients and reduces their loss. Furthermore, the cost-benefit ratio for cropping systems is better when organic manures and mineral fertilizers are used together than when used separately.

Although different kinds of manure have slightly different effects, there is no need for a farmer to go to a deal of trouble in acquiring a specific material; he should use whatever is most easily available to him.
For example, it has been found that for rice fertilization, with or without addition of mineral fertilizers, beneficial effects of almost identical magnitude are obtained by using farmyard manure, crop residues or city waste compost.

More difference - especially from the plant nutrient aspect -is found between different manures of animal origin. Thus poultry manure is richer than cattle manure and so is pig manure; such differences merely modify the quantities to be used or the amounts of other material, say straw, that need to be added if composting.

If a farmer has a biogas digester, its effluent provides a continuous supply of excellent manure that can be used directly and immediately or can be used to assist in composting other organic wastes.

Certain organic materials have specific effects such as the use of blue-green algae for nitrogen supply, but in general all such materials have multiple beneficial effects upon soil conditions.

If a farmer is accustomed to use sulphur coated urea, he may be able to economize by using urea together with rice straw as this has been found just as effective in many regions and if mineral nitrogen fertilizers tend to be lost rapidly by leaching, this can often be remedied by use of 'neemcake' as an organic additive.

The beneficial effects of bulky organic manures when used as a mulch should not be neglected especially as such use entails less labour than if the material is mixed into the soil.

Organic manures, whatever their origin, are bulky, difficult to transport, store and handle and it is therefore tempting for a farmer to neglect manures in favour of mineral fertilizers which are relatively easy to use.

The farmer must, however, realize that if he wants to keep his land fertile, in good tilth and in optimum condition for crop yield and soil conservation, he must ensure an adequate and regular return to the soil of organic matter. For optimum economic results, both the mineral fertilizers and the organic manures should be applied in an appropriate and efficient manner.

The answer to the question Mineral or Organic ? is BOTH.

MINERAL AND ORGANIC

PART II

INTERPRETATION OF EXPERIMENTAL FINDINGS

1. THE EFFECT UPON SOIL PROPERTIES OF MINERAL FERTILIZERS AND ORGANIC MANURES

1.1 Introduction

The research carried out in different countries of Asia has shown quite positively that although mineral fertilizers and organic manures have a beneficial effect upon most soil chemical, physical and microbiological properties when used alone, the effects are greatly enhanced if the materials are used in combination.

There are instances when mineral fertilizers and manures have had a deleterious effect but these are readily explainable with a knowledge of soil type, rates of application, kind of fertilizer or manure and so on. For example, irrational amounts of fertilizer can be harmful to soil; an imbalanced mineral fertilizer can cause deficiencies in available nutrients (excess potassium can result in decreased available calcium or magnesium); acid-forming fertilizers can cause loss of micro-nutrients through leaching or toxicity effects due to liberation of ions such as iron or aluminium. Similarly organic manures sometimes cause plant injury due to toxins but this is usually only a transitory effect and the plants rapidly recover (see section II.3 for further discussion of this phenomenon).

Some soil properties are relatively unaffected by normal fertilizer or manure applications, for example pH value and conductivity (soluble salt content), whereas others such as organic carbon, available nutrients and most physical properties can be profoundly affected when organic manures are used.

1.2 Physical Properties

1.2.1 General

The literature (for Asia) contains very little quantitative information on the effects upon soil physical properties of mineral fertilizers or organic manures. The general consensus is that long use of mineral fertilizers alone may have adverse effects upon soil structure and the related properties such as bulk density, hydraulic conductivity and so on. A possible exception is that of phosphatic fertilizers. The overall effect of organic manures is beneficial due to improved soil structure. A special case is that of organic material being added as mulch when it has immediate beneficial effects on soil temperature, infiltration and water-holding capacity and, on certain prone soils it prevents surface crusting.

1.2.2 Bulk Density

The few results available indicate that whereas continual use of mineral fertilizers increases the bulk density of a soil, organic manures hardly have any effect. This is explained by the effect of manures maintaining the soil structure which tends to deteriorate with continued application of mineral fertilizers alone. Some typical results are shown in Figure II.1.

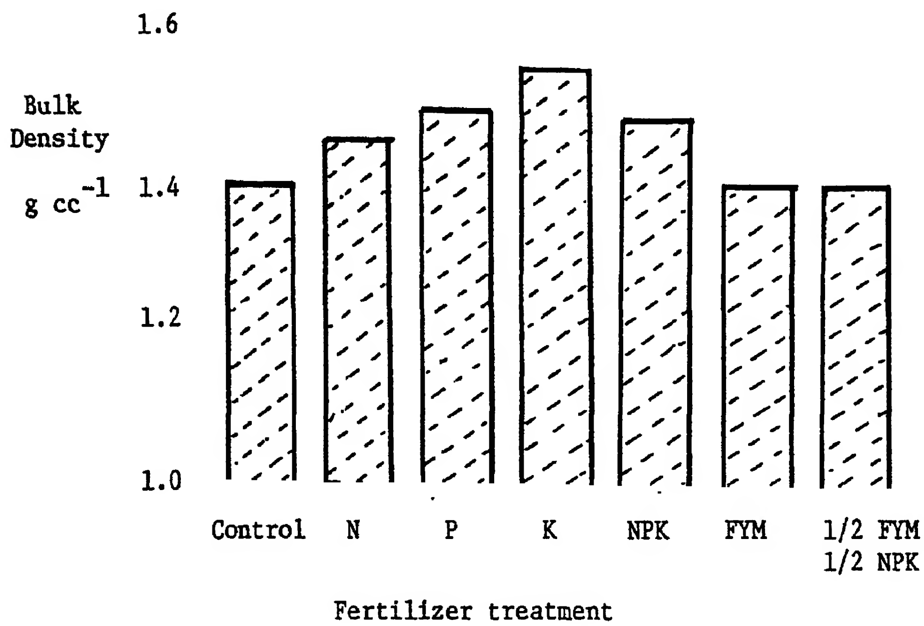


Fig.II.1 The effects of fertilizers and farmyard manure upon bulk density of a soil over a period of 5 years. (Gattani, et al 1976)

1.2.3 Water-holding Capacity

Mineral fertilizers seem to have little effect upon the capacity of soils to hold water whereas a positive effect is given by organic manures (Figure II.2).

1.2.4 Water-stable Aggregates

The percentage of water-stable aggregates greater than 0.25 mm is greatly increased after application of organic manure (Figure II.3). Although nitrogen and potassium fertilizers had no effect, phosphorus also had a beneficial action in building up soil aggregates.

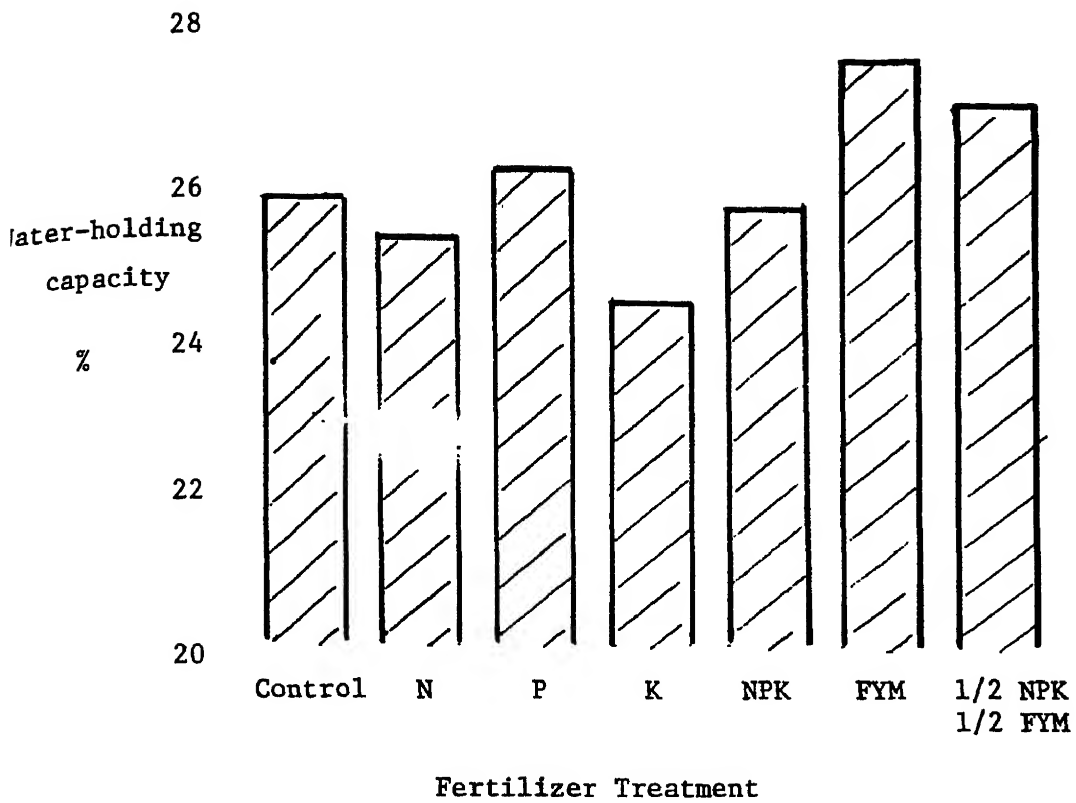


Fig. II.2 The effects of fertilizers and farmyard manure upon the water-holding capacity of a soil over a period of 5 years. (Gattani et al, 1976).

1.3 Physico-chemical and chemical properties

1.3.1 pH values

An analysis of the experimental results shows that whereas continuous use of mineral fertilizers, especially ammonium sulphate, tends to increase soil acidity (due partly to leaching of exchangeable calcium) and that use of fertilizers like sodium nitrate induces alkalinity, organic manures have no lasting effect upon soil pH values. Furthermore, if organic manures are used in conjunction with mineral fertilizers they appear to have a buffering effect which counteracts the tendency of fertilizers to alter pH values. A special case where addition of organic manures can significantly raise the pH value of soils is that where the soil is acid because of excess aluminium. In this case the organic matter forms a complex with the aluminium (or excess iron, if present). However, in some very acid soils - acid sulphate soils for example - the organic matter does not decompose sufficiently to be effective. At present it would seem a matter of trial, using different kinds of organic manures, to see if any beneficial effect is obtainable or not.

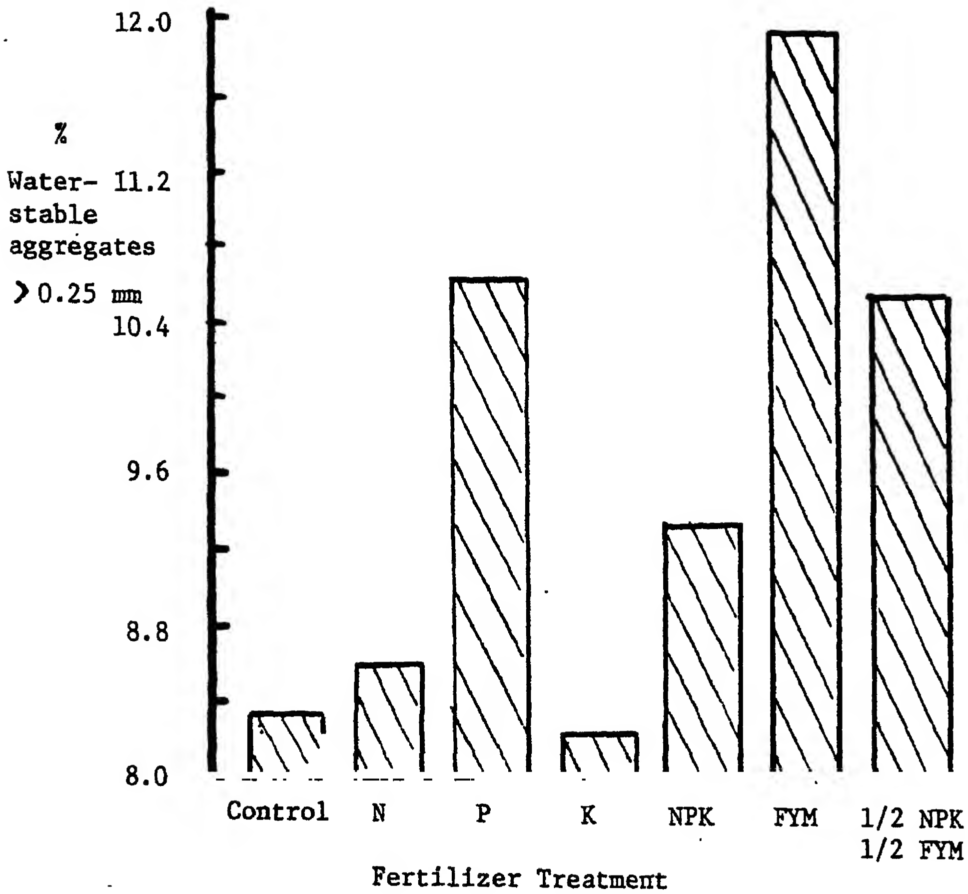


Fig.II.3 The effects of fertilizers and farmyard manure upon the percentage in a soil of water stable aggregates over a period of five years. (Gattani et al, 1976)

1.3.2 Electrical conductivity

Conductivity is a measure of the salt content of a soil. Few investigations have been made in Asia of the effects upon conductivity of fertilizers or manures but it is logical to expect an increase after adding mineral fertilizers which, normally, are soluble salts. However, such increase would be short lived and under normal conditions fertilizers do not result in a soil becoming saline. Experiments with manures show that on the whole, no change in conductivity occurs. On the other hand, it is generally found that with saline or alkali soils, the addition of organic manures helps in their reclamation. The use of green manures together with phosphatic fertilizers has been found to increase greatly the effectiveness of the phosphorus in saline soils. With sodic soils organic manure applied together with gypsum enhances the effect of the latter.

1.3.3 Cation exchange capacity

The overall conclusion of investigations in Asia has been that organic manures, with or without mineral fertilizers, increase the capacity

of a soil to retain cations. This is to be expected as organic matter itself has a high cation exchange capacity - bigger than that of the clay fraction of a soil - and thus any procedure which results in adding organic matter to a soil will automatically raise its exchange capacity; this is one of the major benefits from using manures. A few workers have reported that mineral fertilizers alone can also increase the cation exchange capacity of soils.

Organic compounds tend to lose hydrogen ions from groups such as hydroxy (-OH) and carboxy (-COOH) by dissociation. This leaves the humus particle with a negative charge and thus a capacity to attract bases. Thus adding organic matter to a soil will provide extra sites for retention of soluble plant nutrients which may otherwise leach away.

It has also been found that the exchange capacity of plant roots is increased by mineral nitrogen, organic manures and their combination; potassium and phosphorus alone have little effect (Figure II.4).

1.3.4 Organic carbon

It is not surprising to find that all investigators have concluded that long term application of organic manures to a soil increases the organic carbon and humus contents. However, due to the rapid oxidation of soil organic matter in most countries of Asia, the build up may not be spectacular - although one researcher has reported an increase of up to forty percent over control during a period of forty five years.

In general, mineral fertilizers have little effect upon organic carbon content (Figure II.5); nitrogen can even cause a decrease in carbon due possibly to an induced increase in microbial oxidation of organic matter. Where nitrogen fertilizers have apparently increased organic carbon content, this can be attributed to increased vegetative growth resulting in more crop residues being incorportaed into the soil.

1.3.5 Total nitrogen

Although some workers report that neither mineral fertilizers nor organic manures significantly affected soil nitrogen content (and this was probably a special soil effect), the general conclusion is that both treatments will increase the nitrogen content. Application of mineral nitrogen will naturally increase soil nitrogen, but this may be only a temporary effect depending upon crop uptake, denitrification and leaching. Optimum results seem to be from complementary use of materials (Figure II.6) although this is by no means a universal finding (e.g. Figure II.7).*

1.3.6 C/N ratios

Changes in carbon-nitrogen ratios due to mineral fertilizers and organic manures can be predicted from the changes found in total quantities. The immediate effect of most manures is to widen the ratio, mineral nitrogen fertilizers will narrow it and complementary use has, in the long run, little effect. The values quoted in Table 10 (Part III) show the relatively negligible effects of all treatments.

* Puranik found no difference in total N with application of NPK after the 8 year period; the apparent big differences as in Fig.II.6 is an effect of scale and units, the actual increase in total N here was only 0.008%.

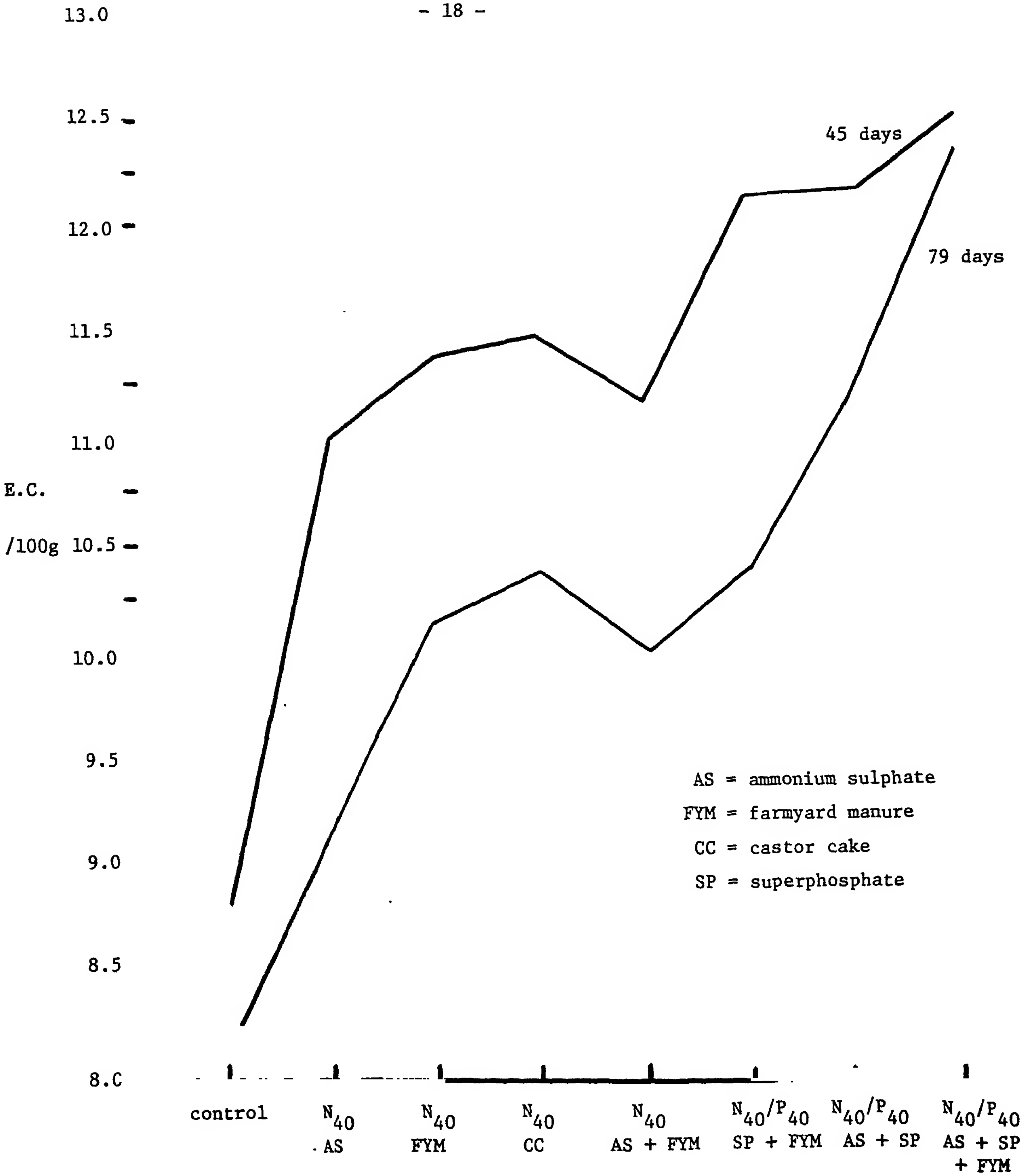


Fig.II.4 Cation exchange capacity of wheat roots in long term permanent manurial trials. (Mehrotra and Saksena, 1970).

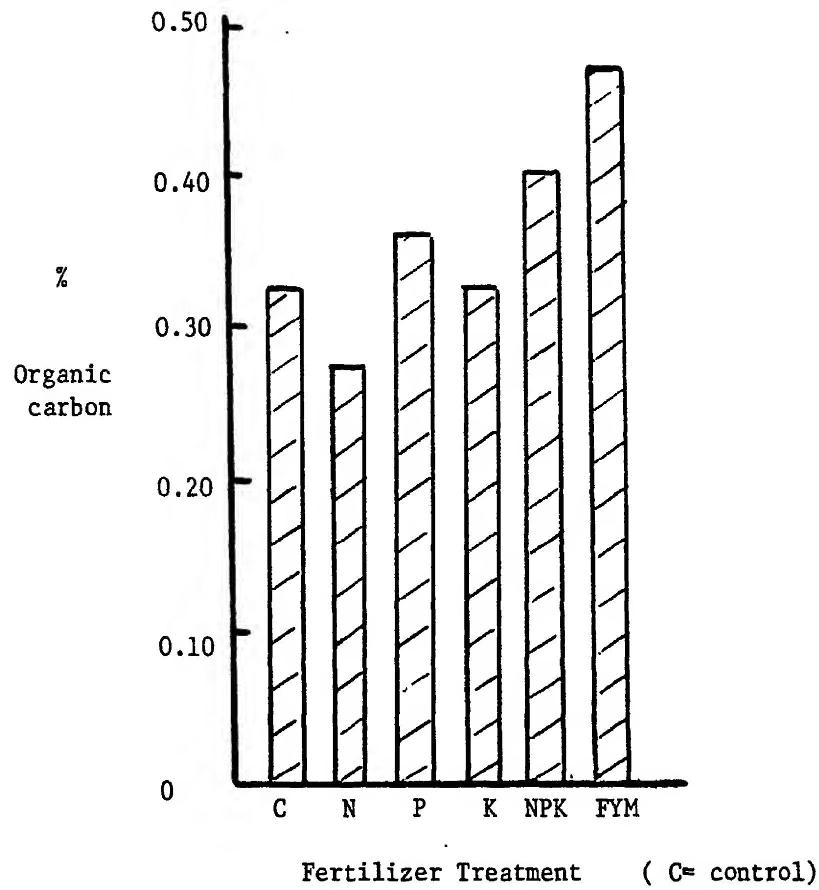


Fig.II.5 The effects of mineral fertilizers and farmyard manure upon the content of organic carbon in soils.

Long term manurial trial, 1930-31 to 1968-69. (Maurya and Ghosh,1972)

1.3.7 Available plant nutrients

i) Available nitrogen

The immediately available nitrogen in a soil is that in the form of nitrate or ammonium and thus addition of mineral nitrogen fertilizers will increase, for a time, the available nitrogen. This is perhaps the main reason for the spectacular results of mineral fertilizers. However, depending upon the kind of soil, this easily available nitrogen may be only temporary; it can be leached, denitrified or fixed and in each case is virtually lost as a plant nutrient. Fortunately most agricultural soils are able to adsorb nitrogen as ammonium on the exchange complex from which it is more slowly available.

The main source of nutrient nitrogen in an unfertilized soil remains that in organic form from which it is slowly released by microbial mineralization. Indeed, the most reliable measure of available nitrogen is that mineralized during incubation of the soil. Thus manuring with organic materials increases the potentially available nitrogen even although the immediate effect may be negative. Much will depend upon the nature of the organic material and its degree of decomposition; in general composts will have longer lasting effects but less immediate fertility than fresh farmyard manure. Figure II.8 shows

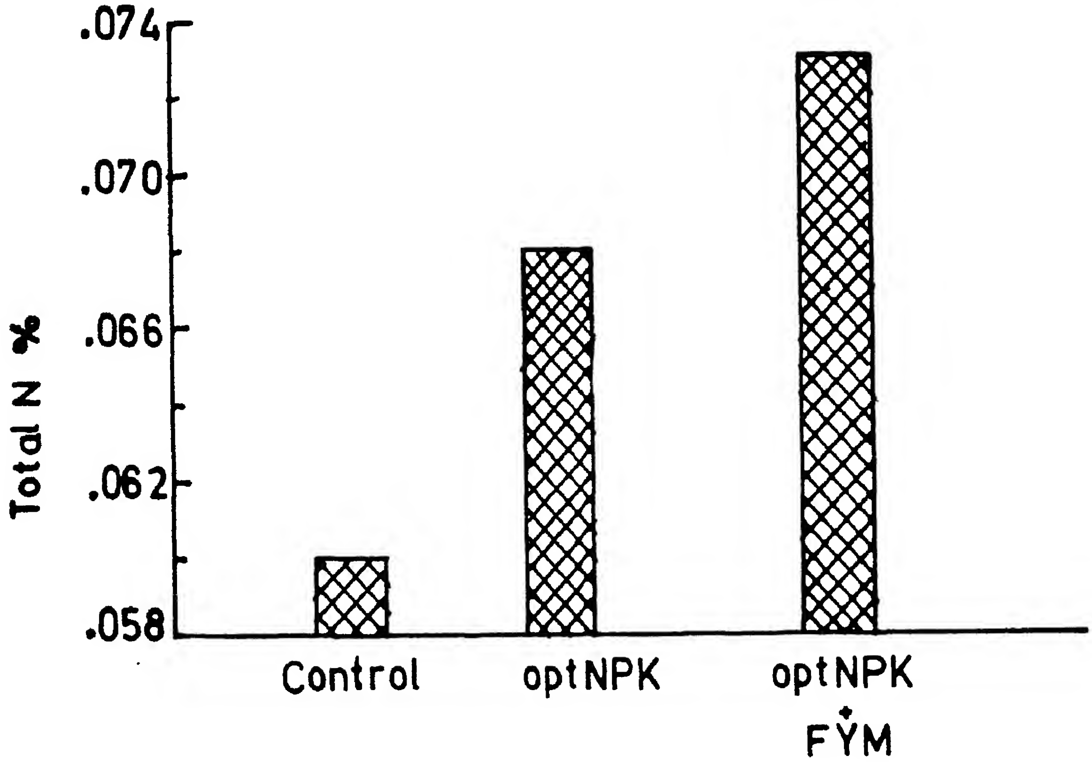
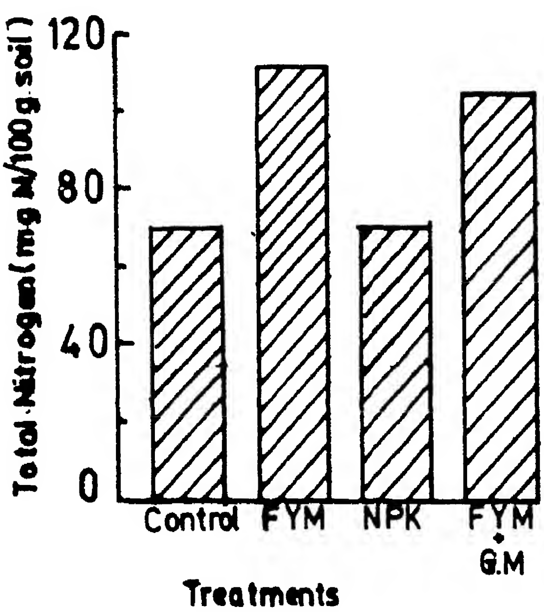


Fig.II.6 The effects upon total nitrogen in soil of fertilizers and farmyard manure. 1973-75. (Swarup and Ghosh,1979).



Figur II.7 Distribution of total nitrogen in surface soil as affected by long term manurial and fertilization treatments (8 years).
(Puranik et al, 1978)

the different effects upon mineral nitrogen immobilization of farmyard manure and the richer, poultry manure. It can be seen that organic manuring first immobilizes available nitrogen but after about three weeks a steady mineralization takes place. Assuming a continued lineal rate of mineralization, all samples would have the same amount of available nitrogen after about four months and, possibly (depending upon total amounts) those soils with organic manures would continue to slowly release nitrogen in excess of that added as fertilizer.

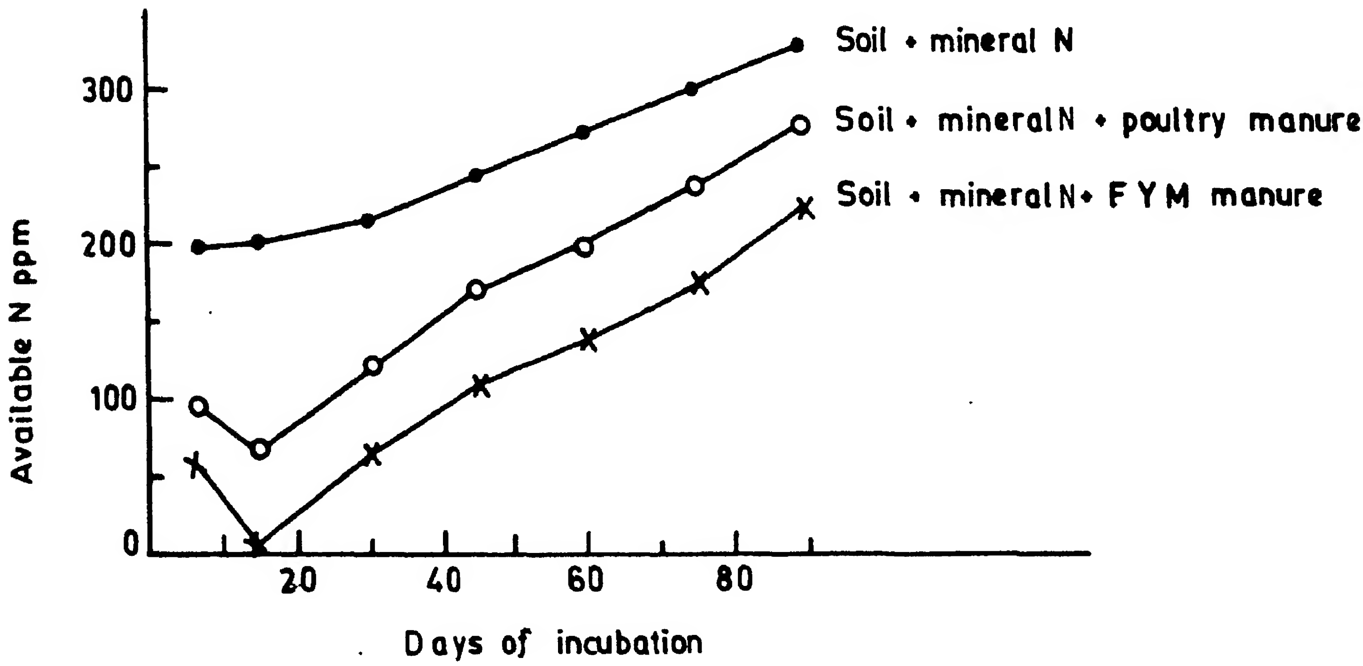


Figure II.8 Effect of poultry manure, farmyard manure and mineral nitrogen upon available nitrogen in a soil (Singh and Srivastava,1971) One year experiment, 1968-9.

Figure II.9 shows the distribution of mineral nitrogen fractions in a soil as affected by long term (8 years) treatment with mineral fertilizers and manures. It was found that nitrate nitrogen was decreased in the presence of farmyard manure, probably due to increased microbial activity depleting the most readily available form of nitrogen. However, if green manure and farmyard manure were used together the nitrate content increased; no explanation for this was found.

Properties of the soils themselves will also play an important part in the nitrogen status as affected by organic manures. For example in soils having much allophane (Andepts for example) this mineral reacts with organic matter to form complexes extremely resistant to mineralization. Thus, in spite of high organic matter contents, such soils still need mineral nitrogen fertilizers. Rice soils, which are normally waterlogged, retard decomposition of organic matter and so manuring of paddy fields may not always be feasible. However, green manures such as Azolla, which provide significant amounts of nitrogen,

appear to be readily decomposed in such soils. Furthermore, in China wet soils are manured with compost (from river silt and rice straw) specifically for growing Azolla.

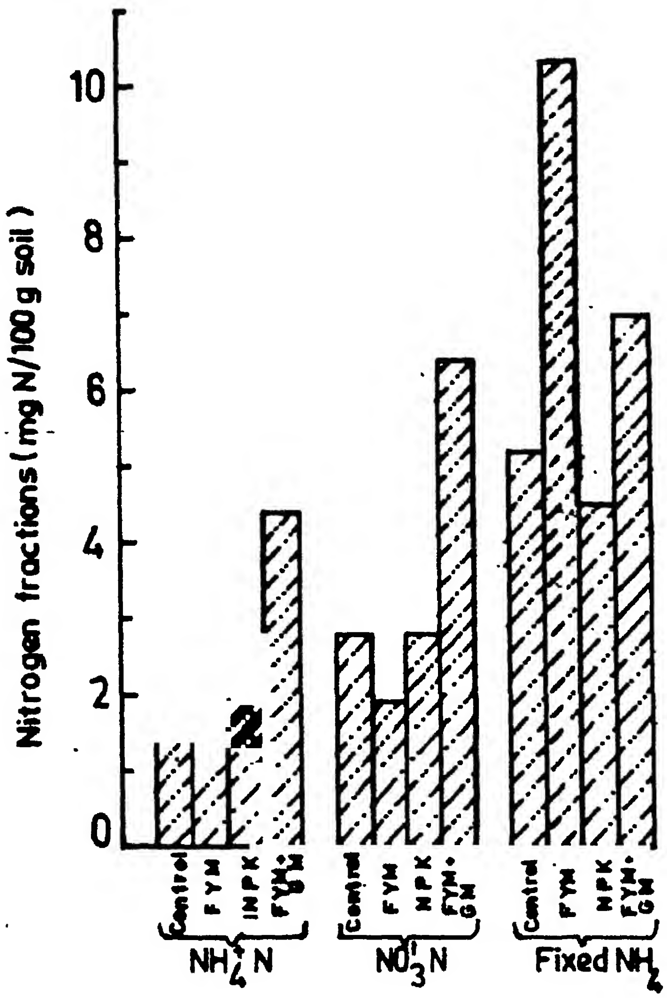


Figure II.9 Distribution of nitrogen fractions in surface soil as affected by long term manuring and fertilization (8 years). Puranik *et al*, 1978)

ii) Available phosphorus

Investigations have shown quite positively that the highest availability of phosphorus is attained by the complementary use of mineral fertilizers and organic manures. This can be seen from the results of a four year experiment using fertilizer alone and with addition of farmyard manure or of city waste compost and which are summed up in Figures II.10 and II.11. The results shown in Figure II.12 show how organic manures can enhance the effects of even sub-optimum dressings of mineral fertilizer. Figure II.10 also reveals the ineffectiveness of farmyard manure as compared to city waste compost.

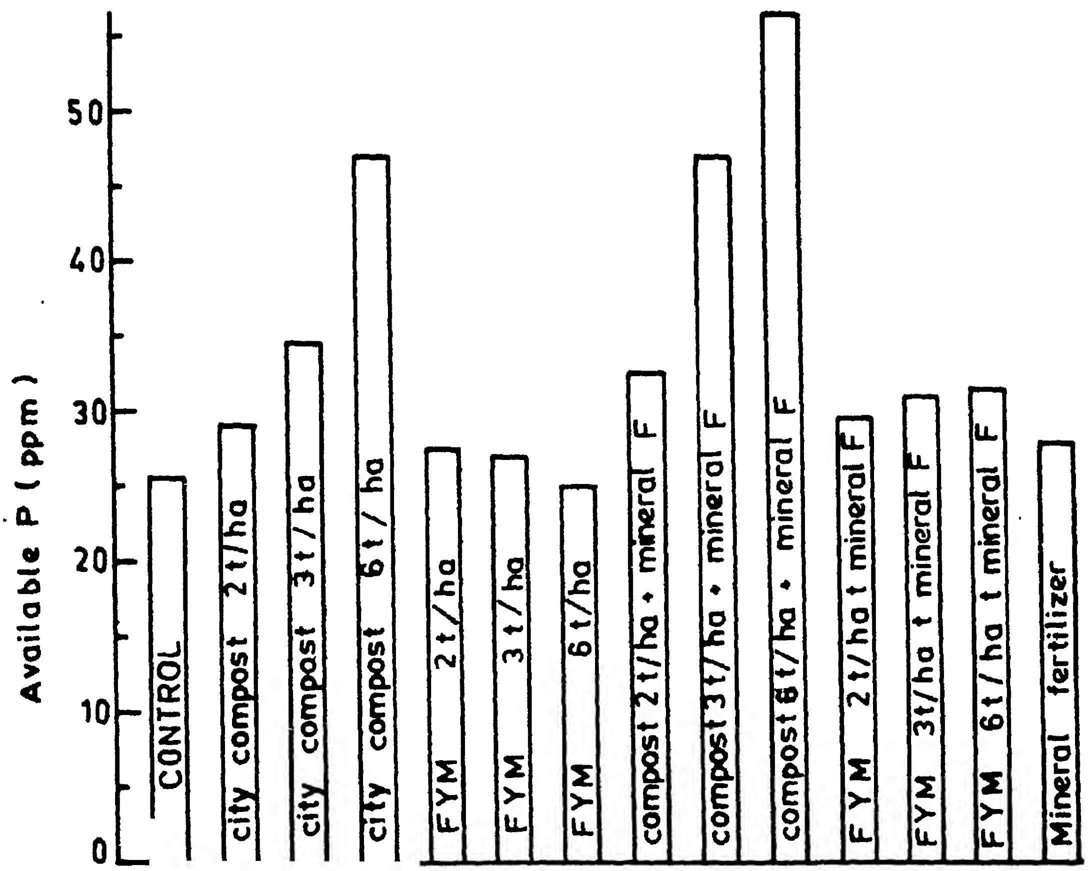


Figure II.10 Effect of various manurial and fertilizer treatments upon the available phosphorus content of a soil (Jugsiyinda *et al* 1978) 4 years experiment.

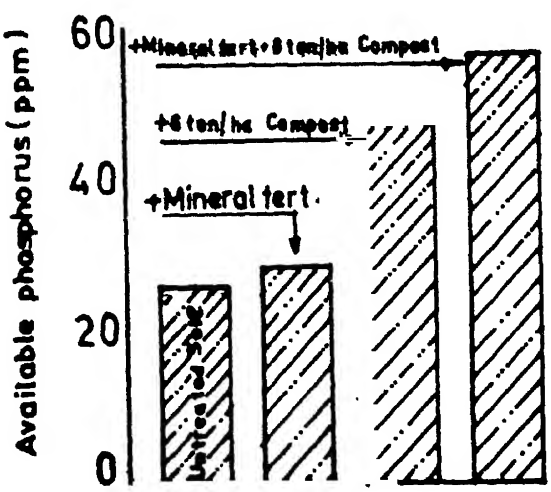


Figure II.11 The overall effect upon available phosphorus in soil of city waste compost with and without mineral fertilizer (Jugsiyinda *et al*, 1978). From Fig.II.10.

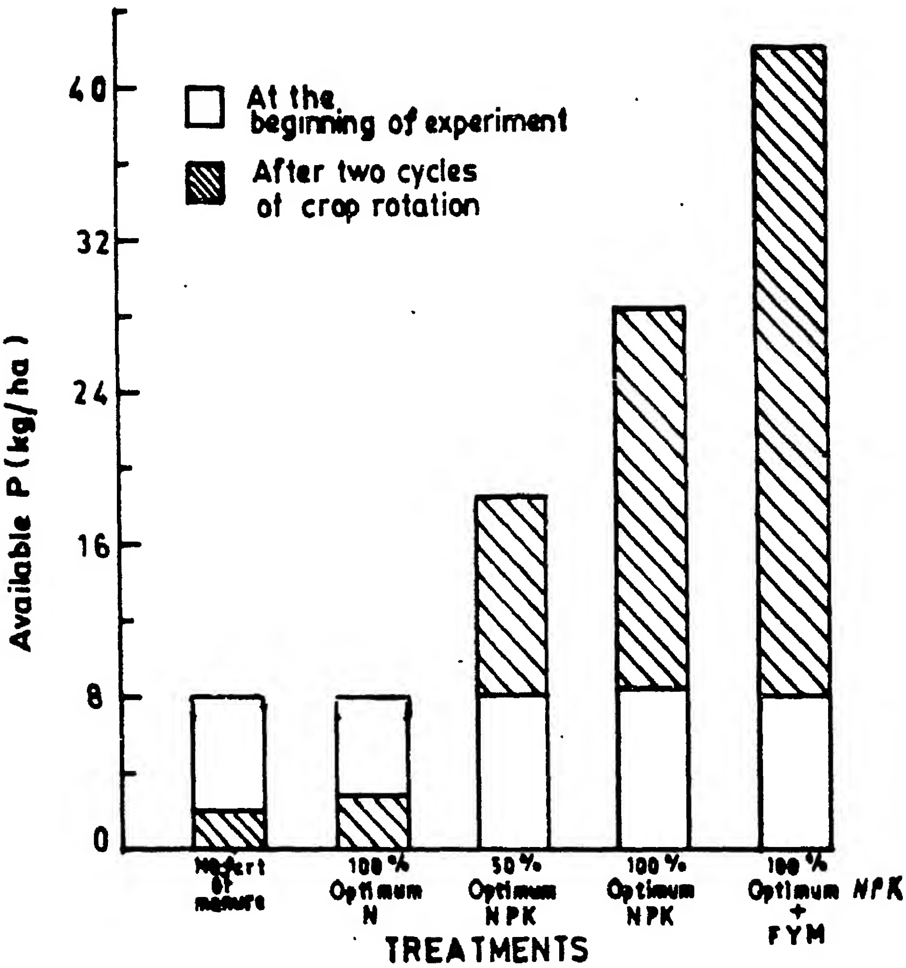


Figure II.12 The effect of continuous application of fertilizer and manure upon the phosphorus status of a soil (Biswas *et al*,1977) After two cycles of crop rotation in a long term experiment.

Organic manures can increase available phosphorus in soil by a number of mechanisms. Firstly by mineralization of the organically bound phosphorus added in the manure; in soils receiving no mineral fertilizer determination of organic phosphorus is the best way of predicting availability. Secondly, in certain soils organic matter forms complexes with iron and aluminium, thus reducing fixation of phosphorus. It is well known that in acid soils aluminium and iron fix phosphorus in unavailable forms and that in alkaline soils a similar process occurs with calcium being the fixing ion. Organic matter can release calcium fixed phosphorus by formation of carbon dioxide which has a solubilizing effect.

On the other hand, organic matter can be responsible for immobilization of mineral phosphorus. This is due to a certain group of microorganisms that utilize only inorganic phosphorus (other organisms obtain phosphorus from organic sources) and so convert mineral phosphorus into their cells as organic compounds. This phosphorus may again become available when the microorganisms

iii) Available potassium

The effects upon availability of potassium as affected by organic manuring have not received as much attention as for nitrogen and phosphorus. However, it is again evident that organic manures increase the effectiveness of potassium fertilizers. Figure II.13 and the original experimental data (Table 17, Part III) illustrate this and further show that available potassium did not increase more even with greater application of the mineral form.

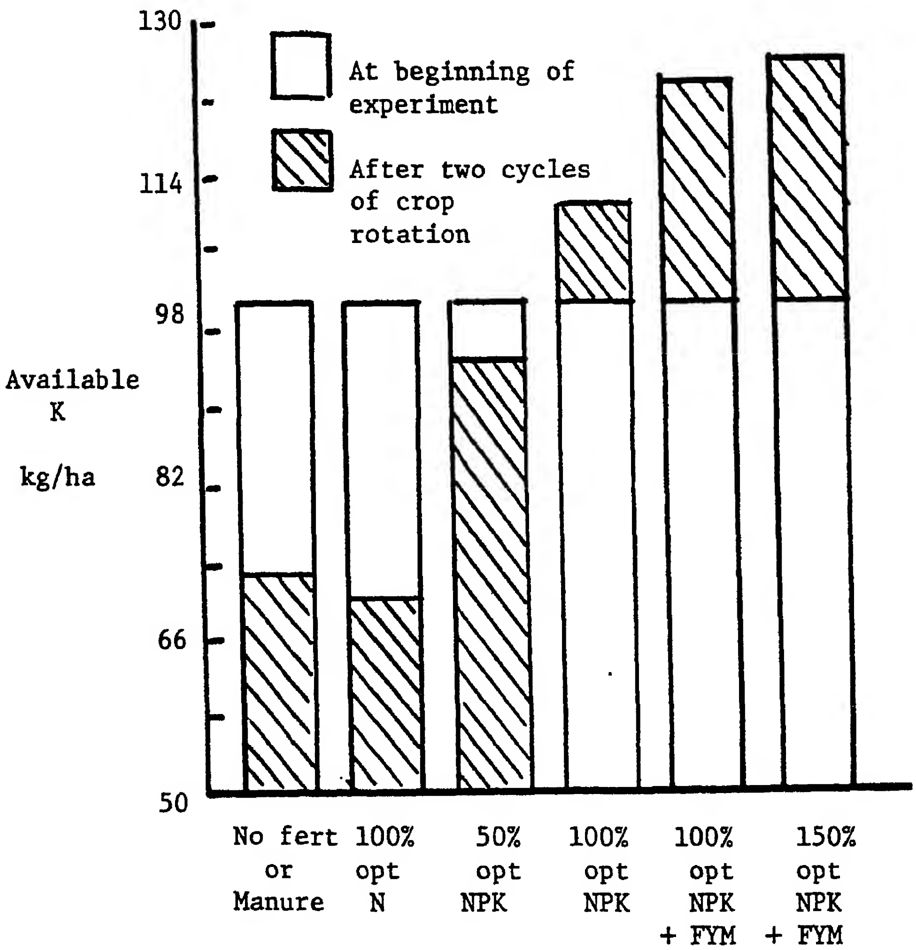


Figure II.13 Effect of continuous application of fertilizer and manure on the potassium status of soil (Biswas *et al*,1977) After two cycles of crop rotation in a long term experiment.

In Figure II.14 is shown the results of an experiment with an acid hill soil that showed little or no response to added phosphorus as regards phosphorus availability but did as regards potassium availability. The interesting fact is the increase in available potassium caused by applying farmyard manure and which exceeded that due to mineral fertilization although accurate interpretation can not be made as the amount of potassium added with the FYM is unknown.

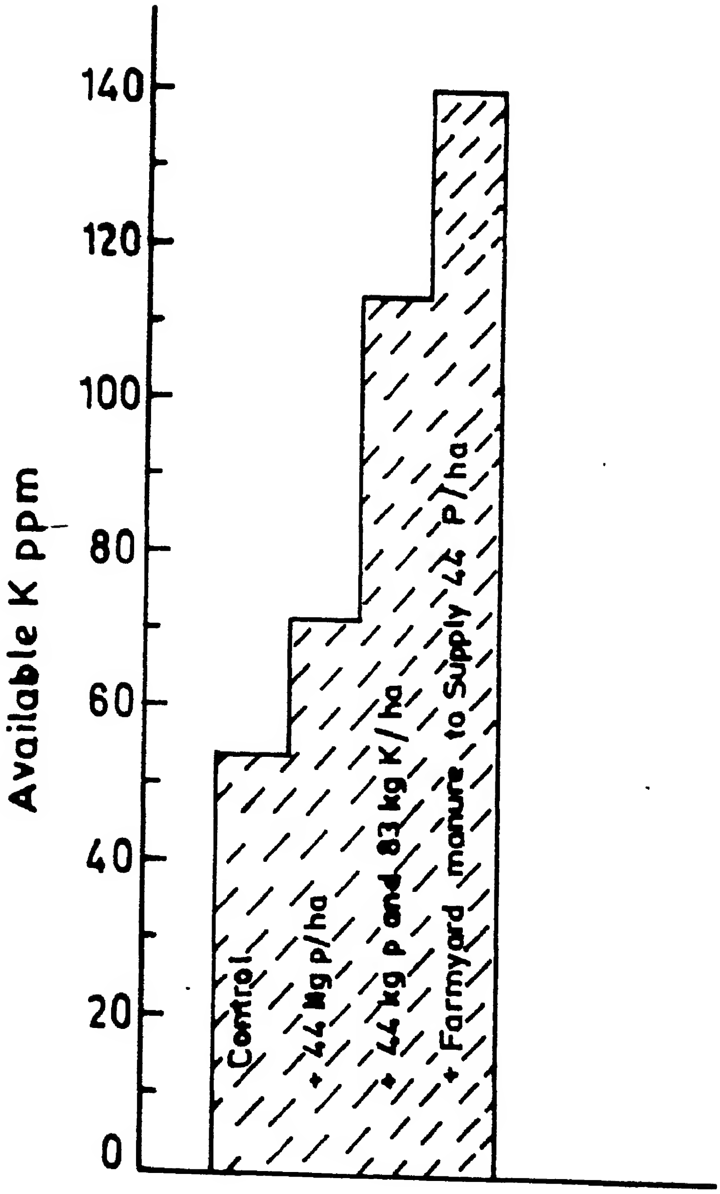


Figure II.14 The effect of manuring upon soil potassium in a long term experiment (Grewal and Sharma,1981) from 1971 to 1980.

iv) <u>Available micronutrients</u>

Micronutrient elements are not supplied to a soil by normal mineral fertilizers unless specifically included and so organic manures are a better source of supply providing that soil conditions are suitable for their release and non-fixation when released.

Cases have been reported where availability of micronutrients has been reduced by mineral fertilizers. For example, nitrogen and phosphorus fertilization can lead to zinc deficiency one explanation being retention in plant roots as a protein complex. On the other hand, acid-forming fertilizers can be expected to increase micronutrient availability.

Highly organic soils such as peats, are usually very deficient in micronutrients; copper deficiency in peat soils is a well known example. Fertilization of such soils with micronutrient containing fertilizers is essential for crop production.

Hardly any work has been done in Asia on this aspect of fertilizing soils and the literature has revealed little information. *

1.4 Microbial properties

The effects of fertilizing or manuring upon microbial activity in soil have received little attention in the region. However, it can be taken that organic manures increase the quantities and activities of microorganisms with, in general, a beneficial result.

Strange as it may seem, peat soils although nearly all organic matter, have been much improved by adding compost and this is due to introduction of a healthy microbial population.

Mineral fertilizers have more specific effects upon microbes. As can be seen from Table 22 (Part III), nitrogen fertilizers can increase some organisms such as bacteria and fungi and yet inhibit growth of Azotobacter. Similarly phosphorus increased the numbers of organisms except for phosphobacteria.

In China, India and the Philippines experiments have shown the superiority of sludge formed by biogas production from organic materials over farmyard manure or compost. The effect can not be explained by the increased nitrogen content and may be due to an induced increase in bacterial activity.

2. THE EFFECT UPON CROP YIELD OF MINERAL FERTILIZERS AND ORGANIC MANURES

2.1 General

As a general, overall statement it can be said that whereas organic manures and mineral fertilizers separately increase crop yields with the largest effect being given by fertilizers, the complementary use of both results in the best yields. This can be illustrated as in Figure II.15 in which is shown the effects of manure and fertilizer separately and together upon the yield of several crops.

Only a small selection of results has been used in this Section to illustrate the principal findings and the reader will find many more in Part III.

2.2 Rice

As rice is the most important crop in the region, the literature contains more references to its reaction to fertilizers and manures than for other crops.

A very clear cut picture of findings in Japan is shown by Figure II.16 and Figure II.17 shows a similar result but also shows how different locations and

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* Stop-press information from Tamil Nadu University is that farmyard manure with $FeSO_4$ gives a phenomenal increase in yield of jasmine flowers over use of $FeSO_4$ alone.

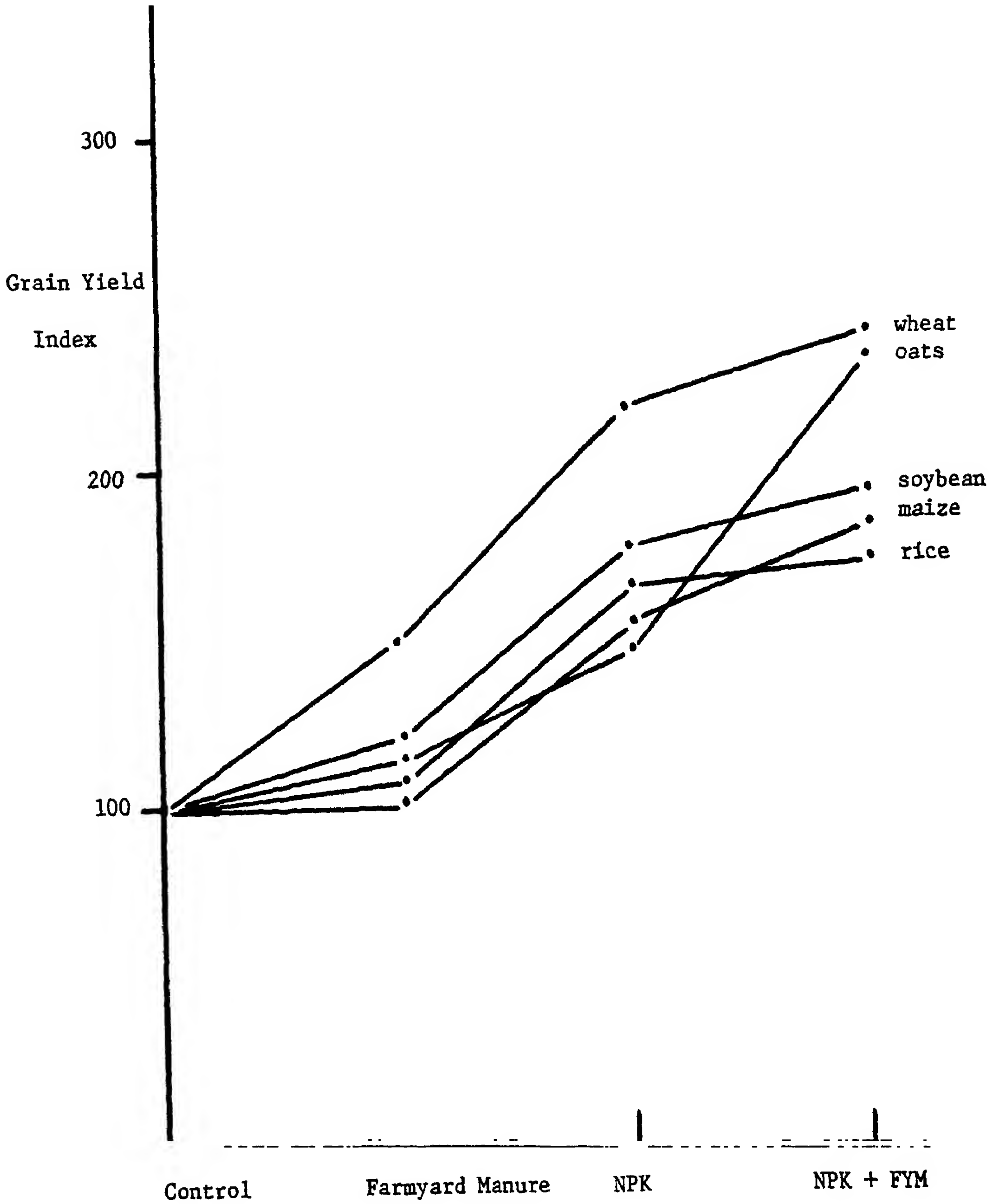


Figure II.15 Effects of farmyard manure and mineral fertilizer upon the yield of different grain crops. (Data from various sources in Asia).

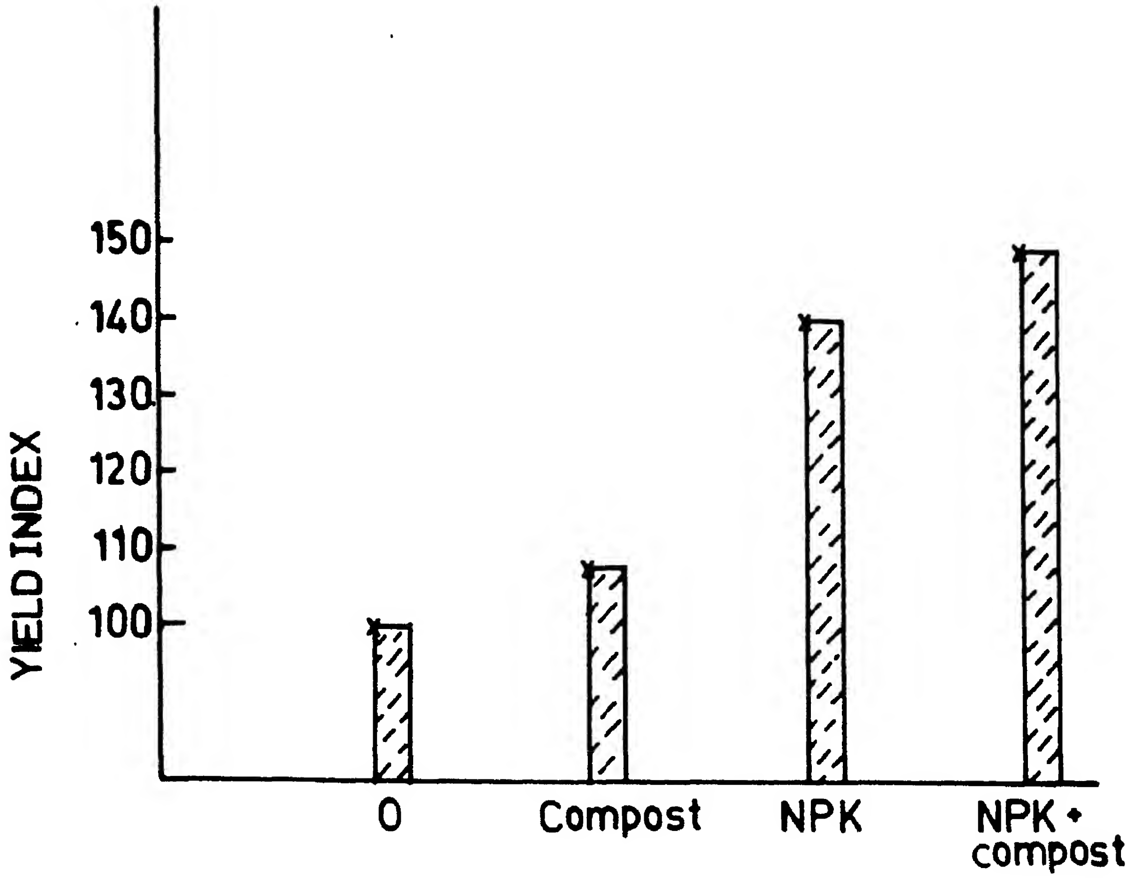


Figure II.16 Effect of mineral fertilizer and compost upon rice yield in Japan (Harada, 1952).

hence different soils, climate and management, affect yield response to manures and fertilizers.

Two different organic manures, farmyard manure and crop residues, are compared in Figure II.18 but give an almost identical yield increase with and without additions of mineral nitrogen. Similar results have been obtained with city waste compost.

A specific investigation of the effects of urea upon rice yield has been made and the results (Figure II.19) show that urea blended with rice straw gives yield increases comparable to sulphur coated urea in wet and flooded conditions.

The cumulative and residual effects of fertilizers and manures over a ten year period showed that farmyard manure alone was better than mineral fertilizer even the combined NPK. This however is not always the case; unfortunately the investigator did not include trials with manure and NPK together (Fig.II.20)

An experiment designed to investigate the effect of fertilizers and farmyard manure on paddy yield in a fixed crop rotation was conducted over a ten year period. The results (Fig.II.21) again show that best effects are given by a mixture of manure and fertilizer. For nitrogen and phosphorus mineral fertilizers the effect of the manure was increased by increased levels of fertilizer but this was not so for potassium. However, even fertilization with different levels of potassium alone affected the yield very little and

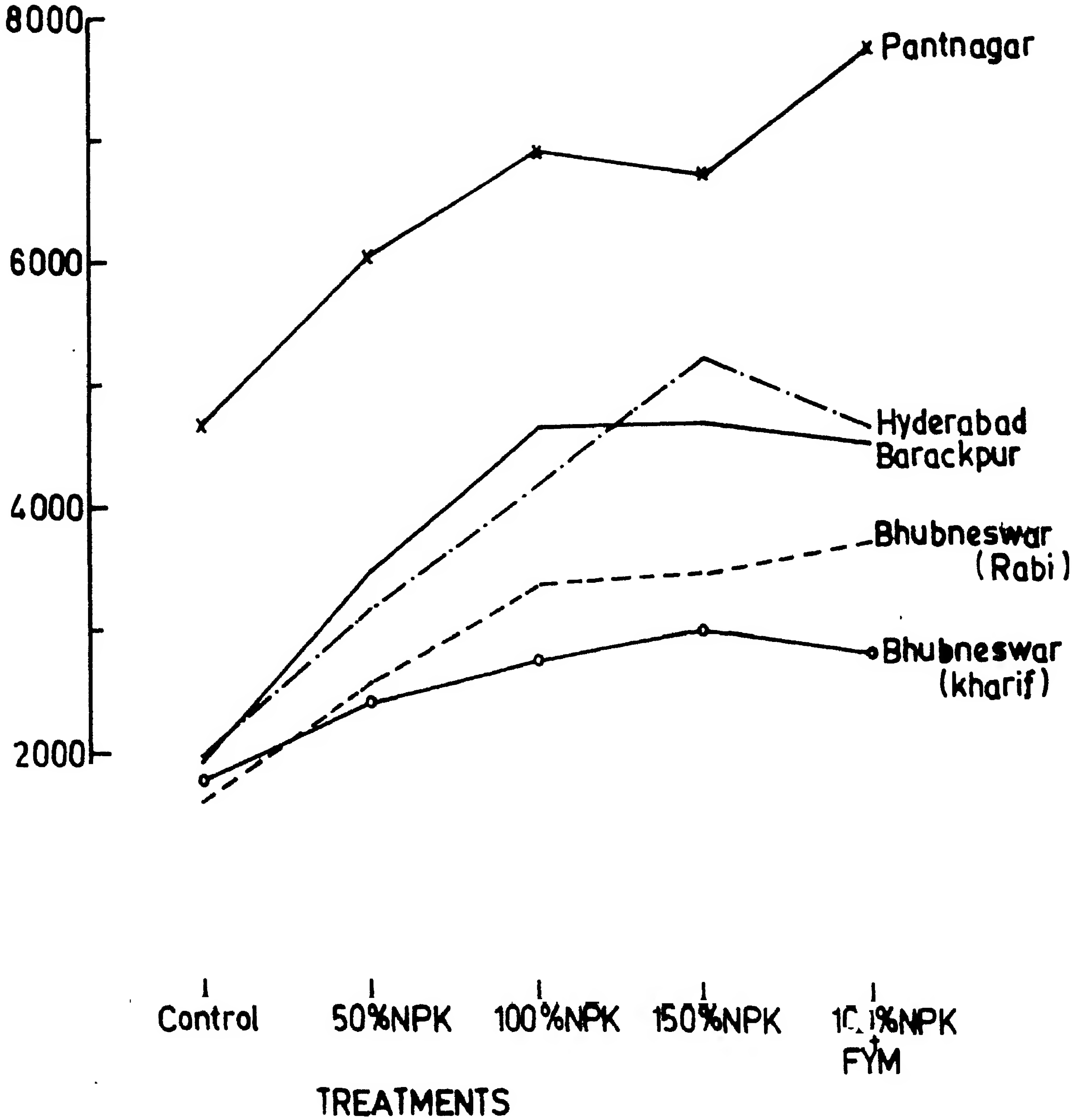


Figure II.17 Average yield of rice as affected by fertilizer and manure treatments at different locations in India during 1971-1979 (Ghosh, 1981)

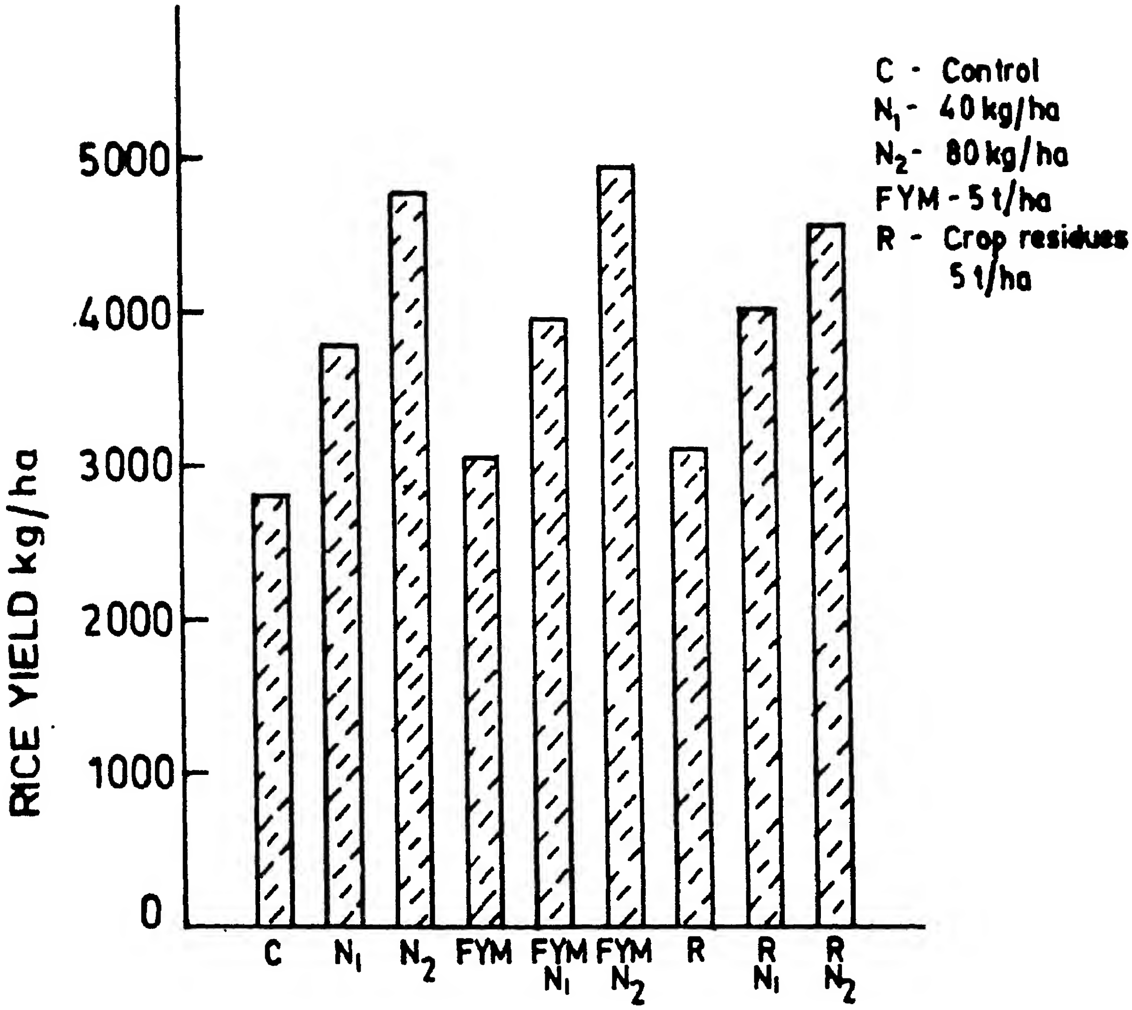


Figure II.18 Yield of rice as affected by mineral fertilizers and organic manure (Pillai,1978) One year experiment.

as nitrogen and phosphorus were the limiting elements, it may be that the effect of the manure when added with potassium was due to provision of these nutrients.

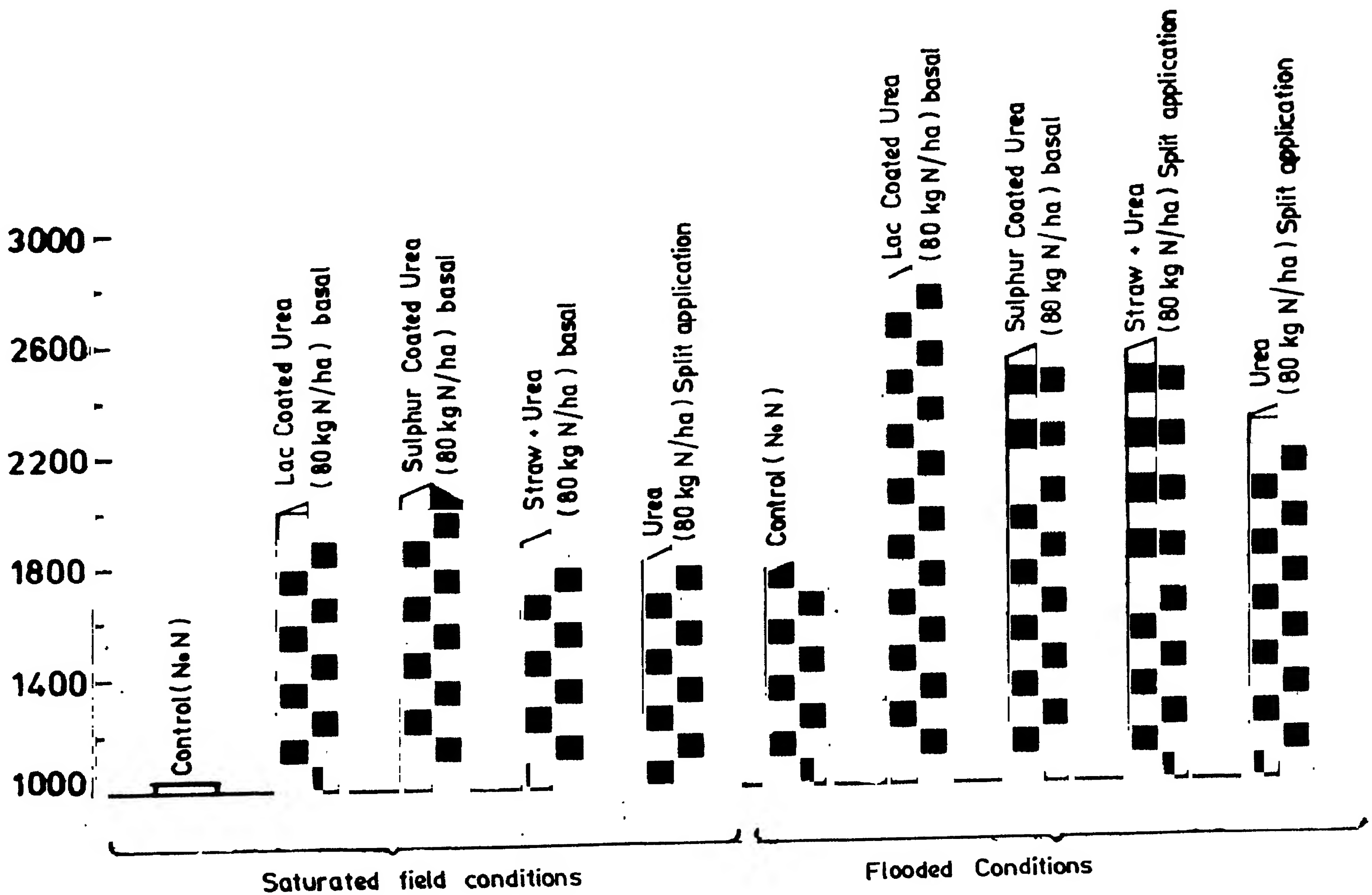
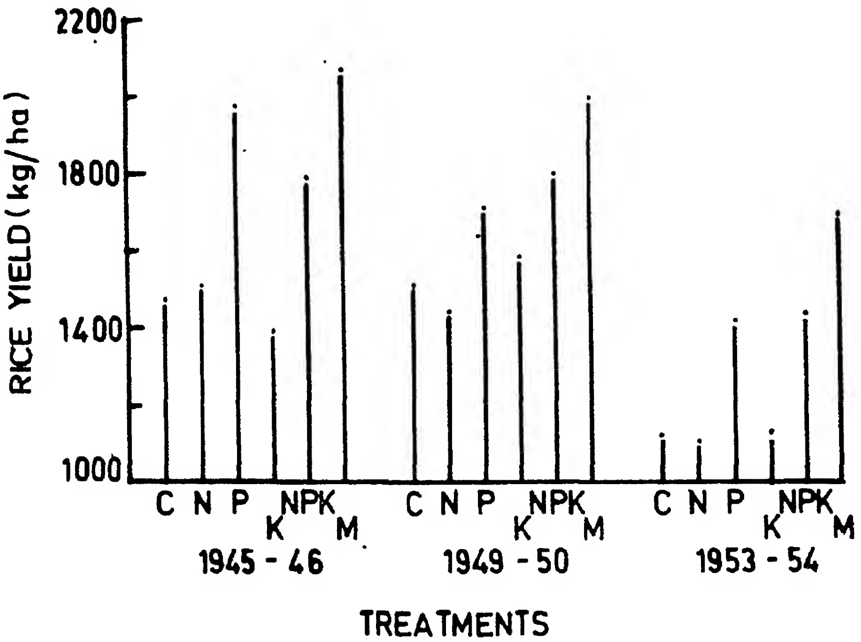


Figure II.19 Efficacy of urea blended with rice straw and soil for improving rice yield (Shinde *et al.*1975) One year experiment.



C-Control, N Ammonium sulphate (40 kg N/ha); P Superphosphate (18 kg P/ha); K- Potassium sulphate (33 kg K/ha), N PK- as above combined M-FYM (40 kg N/ha)

Figure II.20 Cumulative and residual effects of mineral fertilizers and farmyard manure on paddy yield (Thant, 1978) . Long term experiment, 1945-6 to 1953-4.

2.3 Wheat

In Figure II.22 is summarised the data from an experiment on fertilization of wheat grown in a calcareous black clay soil. In every case, addition of manure with mineral fertilizer gave better yields. Also in every case, increased amounts of manure gave increased yields except that when the mineral fertilizer was potassium only, the effect was not significant. The graph has itself been further summarised (Fig.II.23) to show the overall effects upon yield of wheat.

A similar experiment was made in India to show the additional effects of location; the results are shown in Figure II.24. In this experiment it was found that very heavy application of NPK was only marginally superior to normal dressings with addition of farmyard manure.

On a sandy loam soil again the same general results were obtained with wheat and also with soybean (Fig.II.25). The effect of sewage upon wheat yield has been shown (Fig.II.26) to supplement that of mineral fertilizers, the effect being greater with increased dilution of the sewage. Without mineral fertilizers

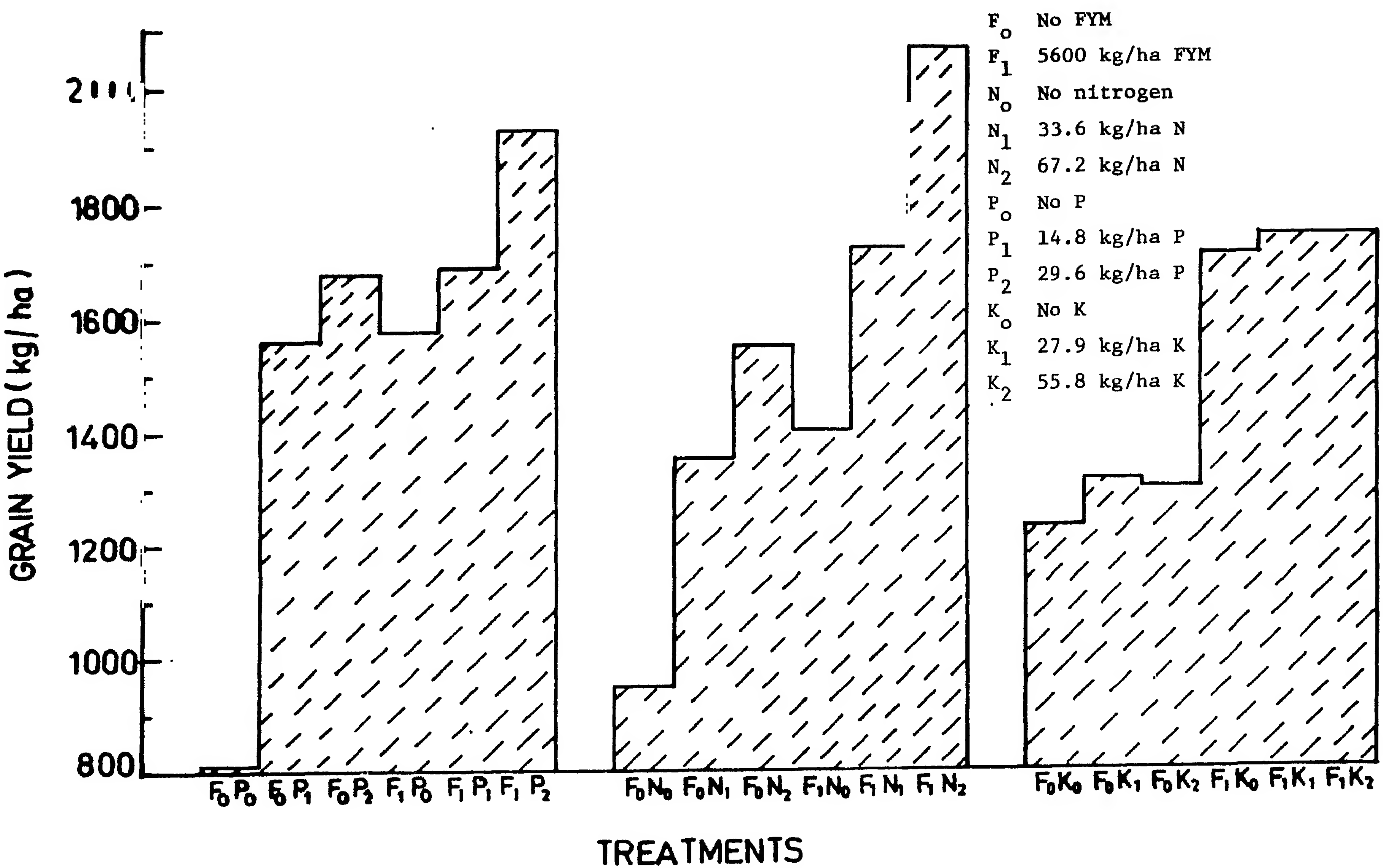


Figure II.21 Mean yield of paddy in a fixed crop rotation experiment at Bagwai, India (Shinde and Ghosh, 1971) Long term experiment 1956-66.

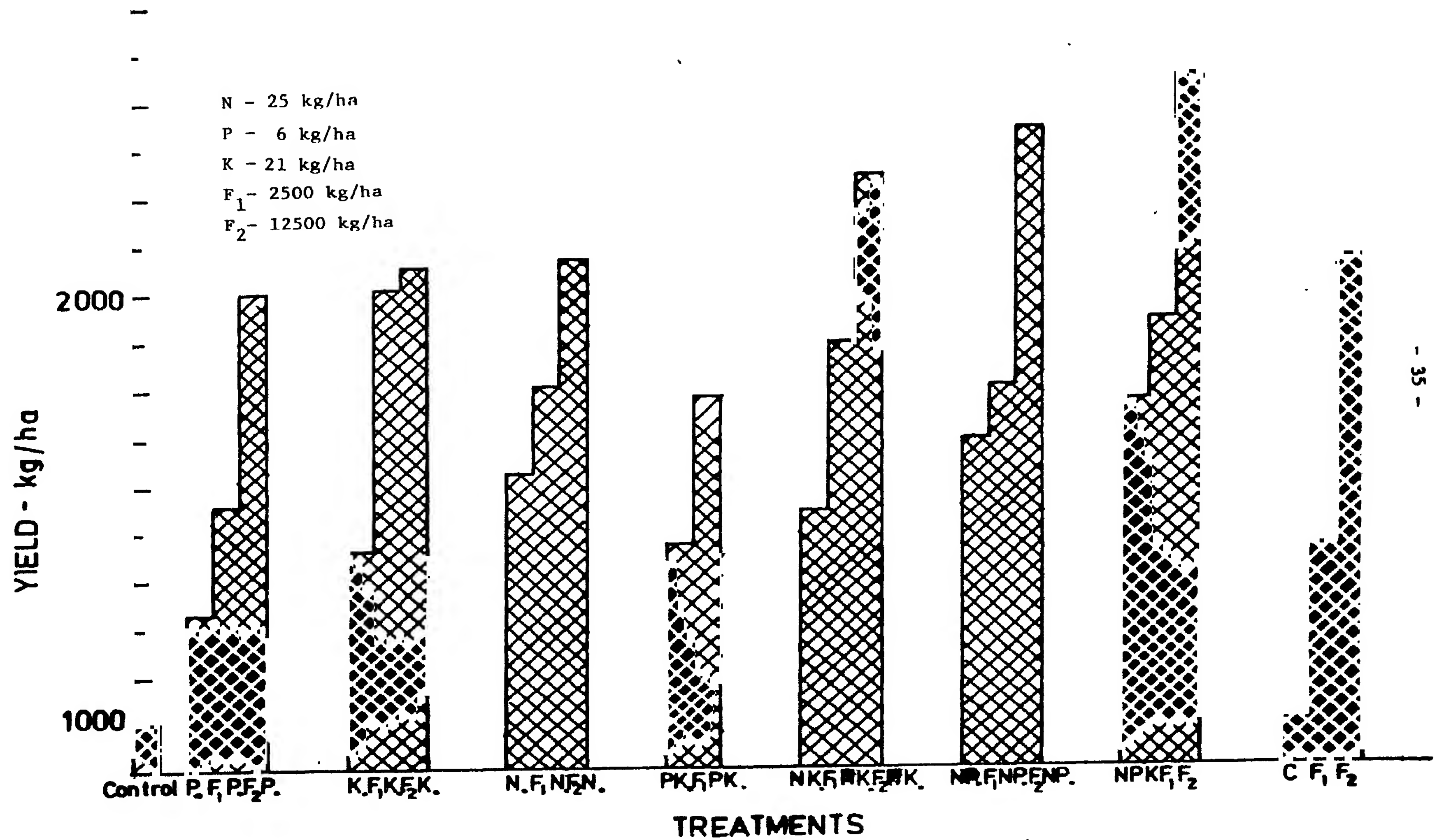


Figure II.22 Effect upon wheat yield of mineral fertilizers separately and in combination with farmyard manure (Naphade and Bhoyar, 1974) 9 year experiment.

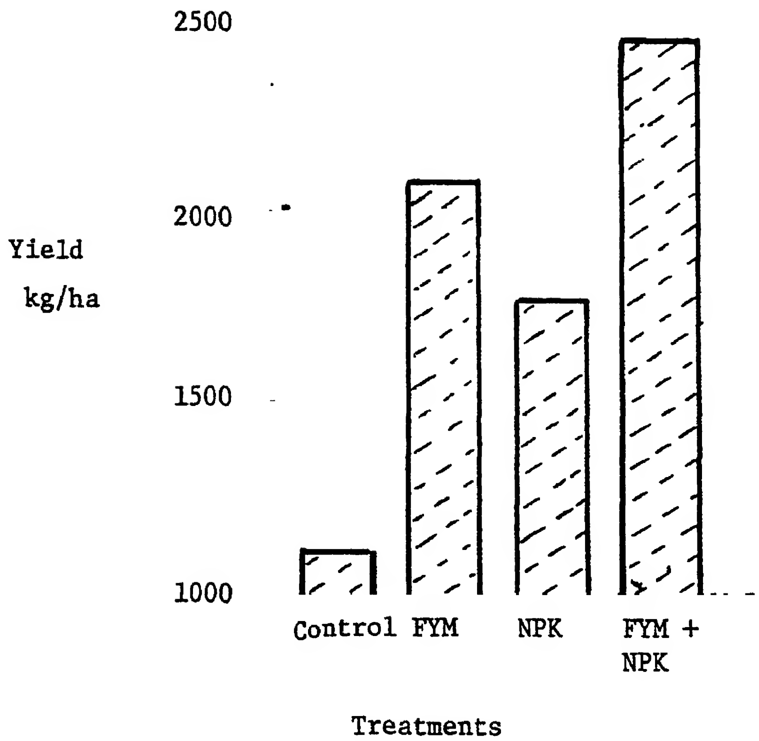


Figure II.23 Net effect of farmyard manure at 12 ton/ha upon yield of wheat with and without mineral fertilizer (Summarized from Fig.II.22).

the more concentrated sewage gave the highest yields. The effect of irrigation water was allowed for by a control plot irrigated with the same quantities of well water.

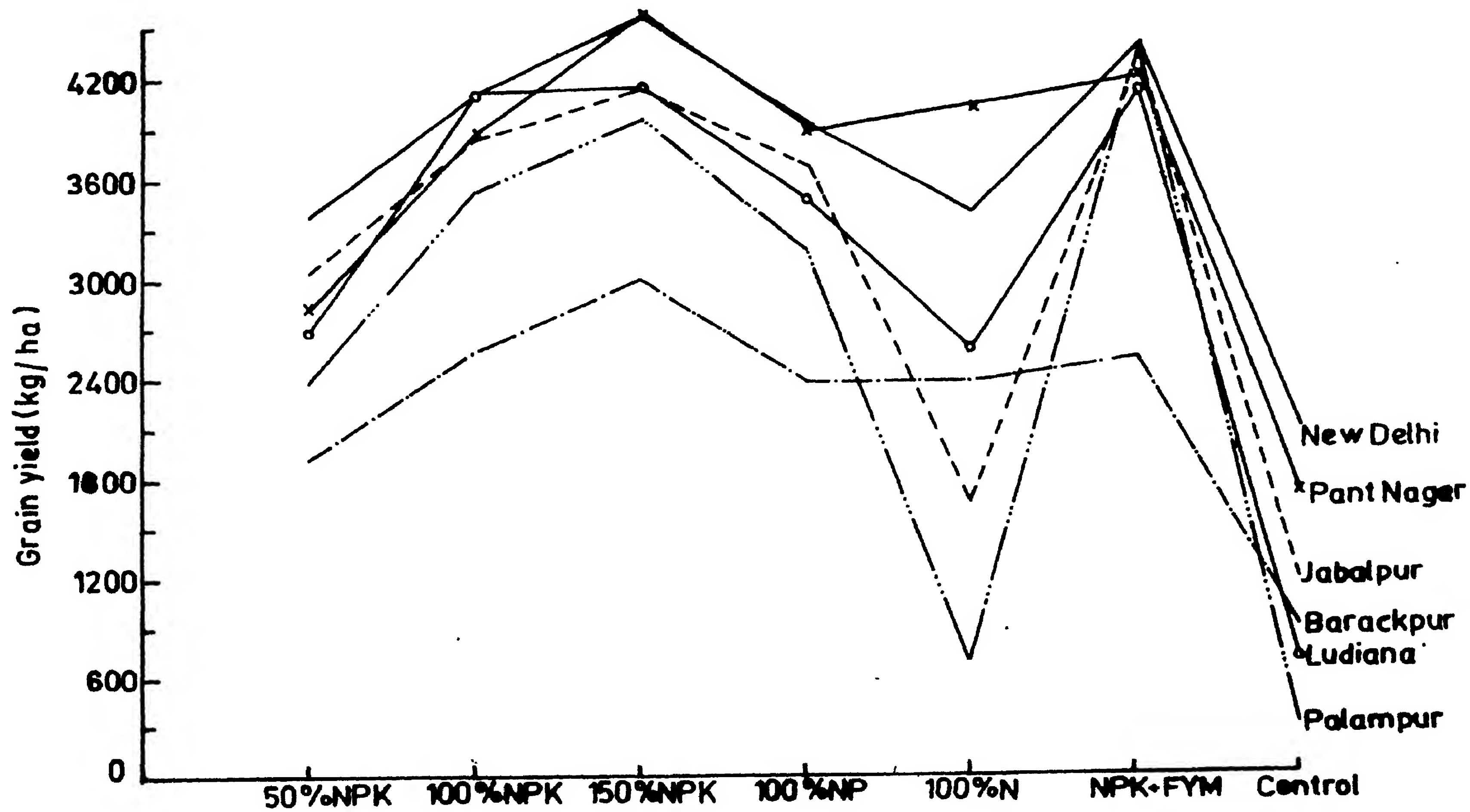


Figure II.24 Average yield of wheat under various treatments over the years 1971-1979 at different locations in India (Ghose, 1981) 8 year experiment.

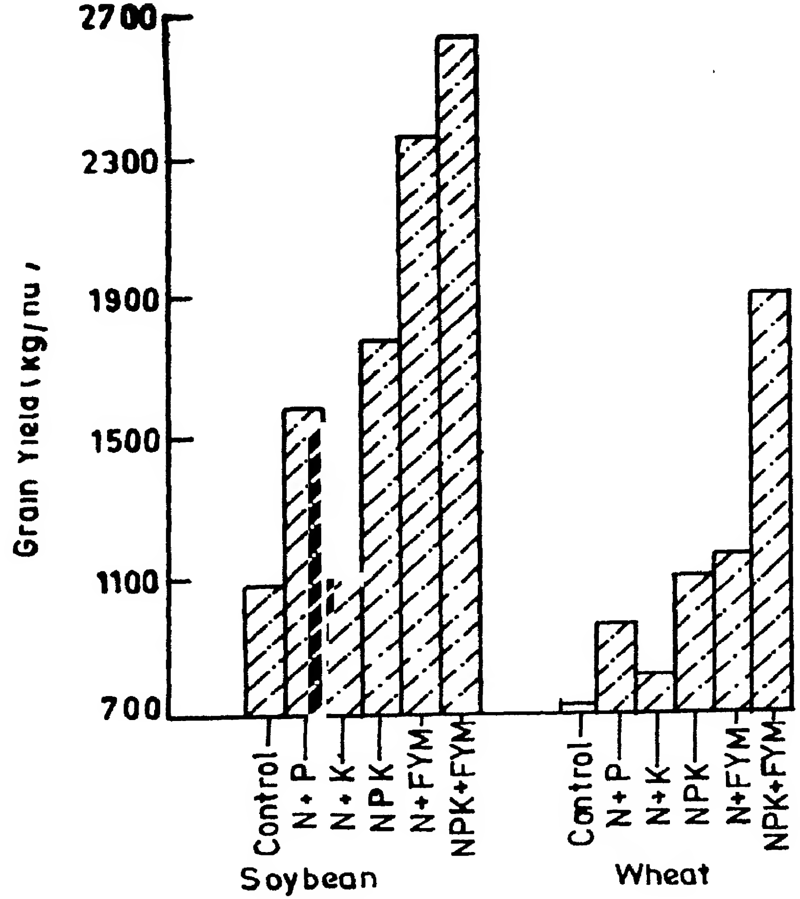


Figure II.25 Effect of mineral fertilizer and manure on the yields of soybean and wheat with a hill sandy loam soil (Tandon and Verma, 1978) Averaged over 5 crops of Rabi and 5 crops Kharif.

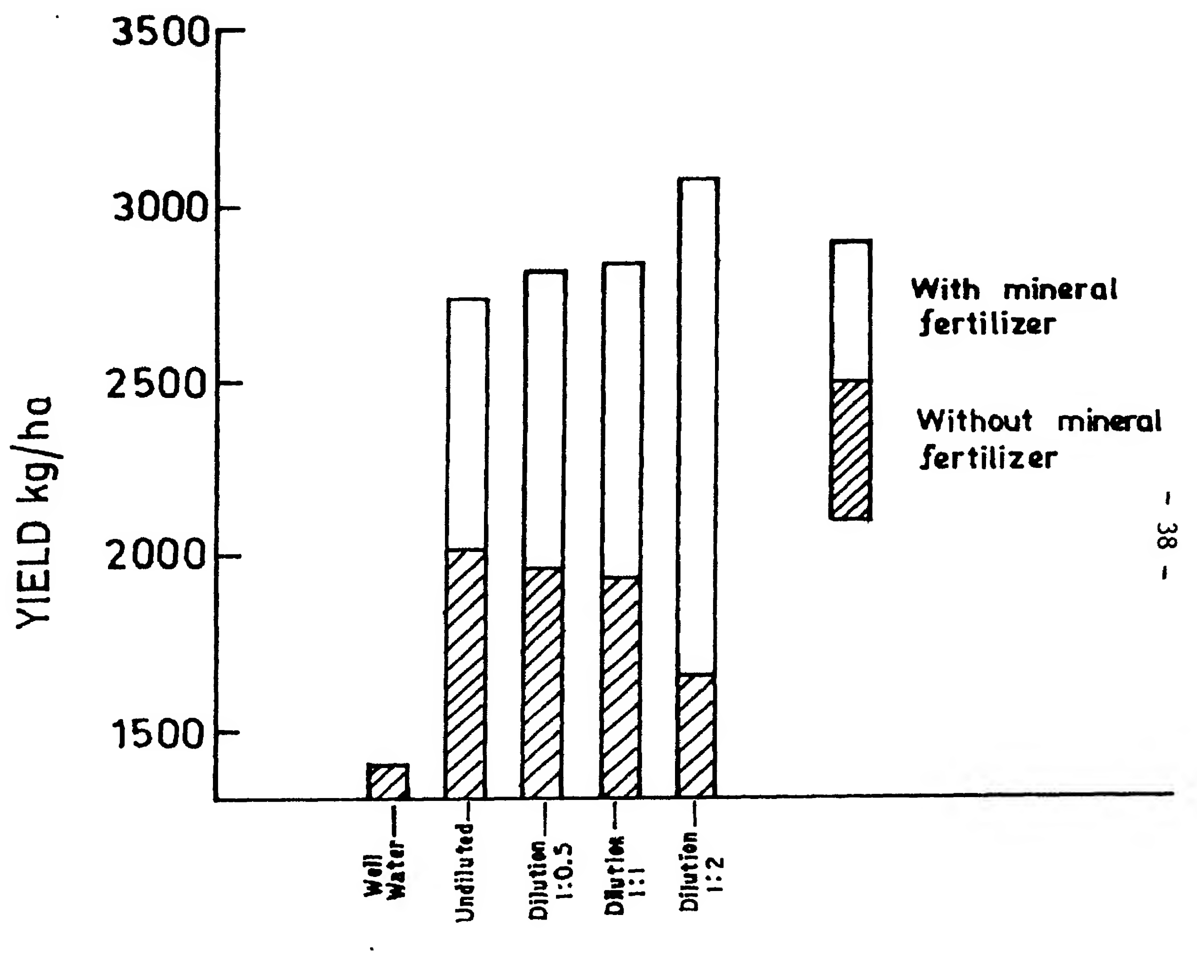


Figure II.26 Additional wheat yield obtained through supplementory addition of mineral fertilizer in sewage farming (Shende and Sundarresan, 1978) 7 year average.

2.4 Maize

An investigation of the fertilization of maize grown in three different locations in India showed (Fig.II.27) how, irrespective of soil and climate, the beneficial effect of mineral fertilizers was increased by using organic manure as well. From the data it can be seen that the least productive locations responded most to mineral fertilizers but application of manure with the fertilizer gave proportional increases in yield of about the same order.

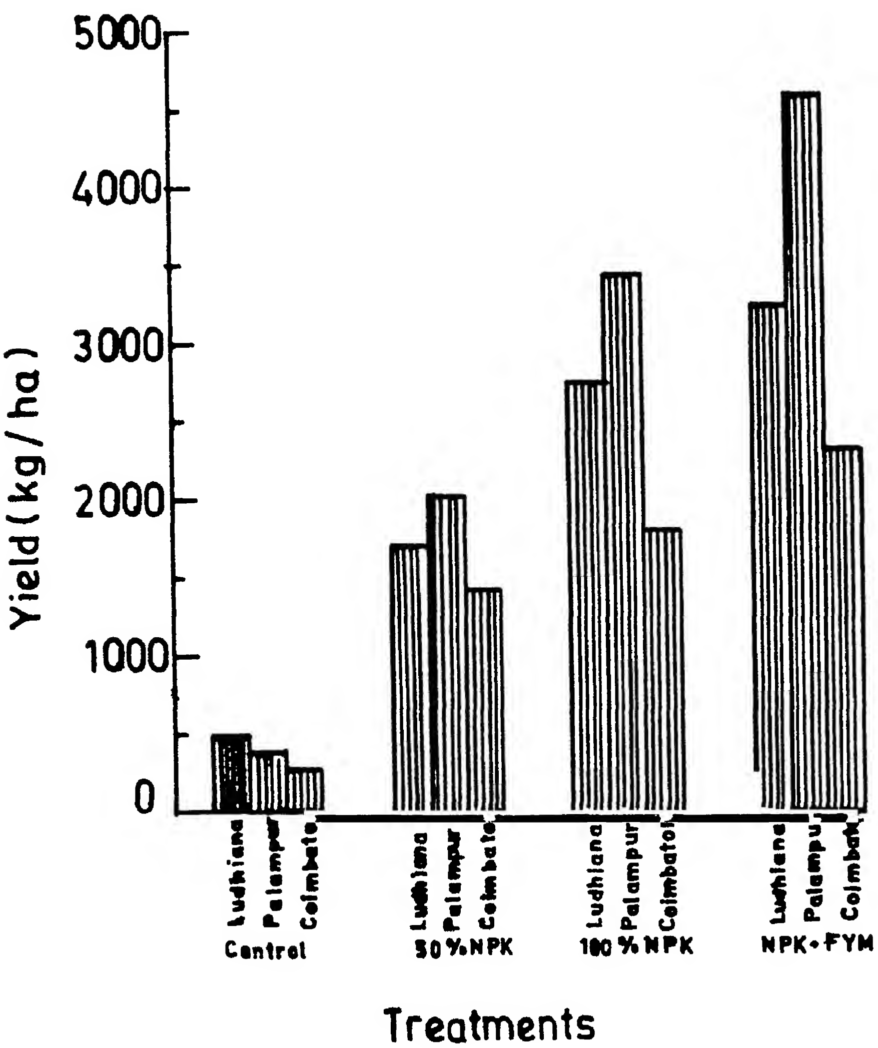


Figure II.27 Yield of maize as affected by manuring and fertilizing in permanent manurial trials at different locations in India during 1971-1979 (Ghosh, 1981)

In an experiment using mineral nitrogen with and without neemcake as manure most soils showed a progressive increase in fertility for maize production with increased nitrogen supply, in each case the effect being enhanced when the neem cake was used (Fig.II.28). An unusual result was found at the location of Khan Das where mineral nitrogen alone had a depressive result upon yield unless neemcake was also added. Similar results showing the effect of neemcake when mixed with ammonium sulphate have been found and the theory suggested is that neemcake inhibits nitrification of the fertilizer and hence its rapid loss by leaching.

2.5 Other crops

Scattered references have been found in the literature giving data showing that complementary use of mineral fertilizers and organic manures gives the best yield response for vegetables, jute, cowpea, soybean, sugar beet, beans, barley, gram, oats, cotton and millet.

Figure II.29 shows the direct, residual and cumulative effects of phosphorus and potassium fertilizers as compared to farmyard manure on potato yield and Figure II.30 compares the effect of farmyard and poultry manures upon potato yield.

A specific investigation of yield of fodder (Berseem) when grown in a sodic soil showed that while amelioration of the soil with gypsum was essential, its effect was much enhanced if farmyard manure was also added (Figure II.31). It can be seen that application of the manure tripled the yield of fodder as compared to application of gypsum alone.

2.6 Green manuring

Green manuring is a special form of organic manuring and again the general conclusion is that use of green manures together with fertilizers is the best practice. An experiment to compare a green manure (sunhemp) with cattle manure showed that the green manure gave slightly better results.

2.7 Azolla and Blue-green Algae

The term biofertilizers has come into popular use to denote (rather inaccurately) algae or plants in symbiosis with algae, and their principal value is that they fix atmospheric nitrogen in organic forms which is mineralized when the plant decomposes in the soil. The most commonly used biofertilizers in Asia are Blue-green algae and Azolla and both have been extensively discussed in other Project Field Documents *.

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* Field Document No.2: Blue-green algae for rice production (FAO Soils Bulletin 46)
Field Document No.12: Small scale integrated farming
Field Document No.18: Algal biofertilizer technology for rice (with slides)
FAO Soil Bulletins Nos. 40 and 41

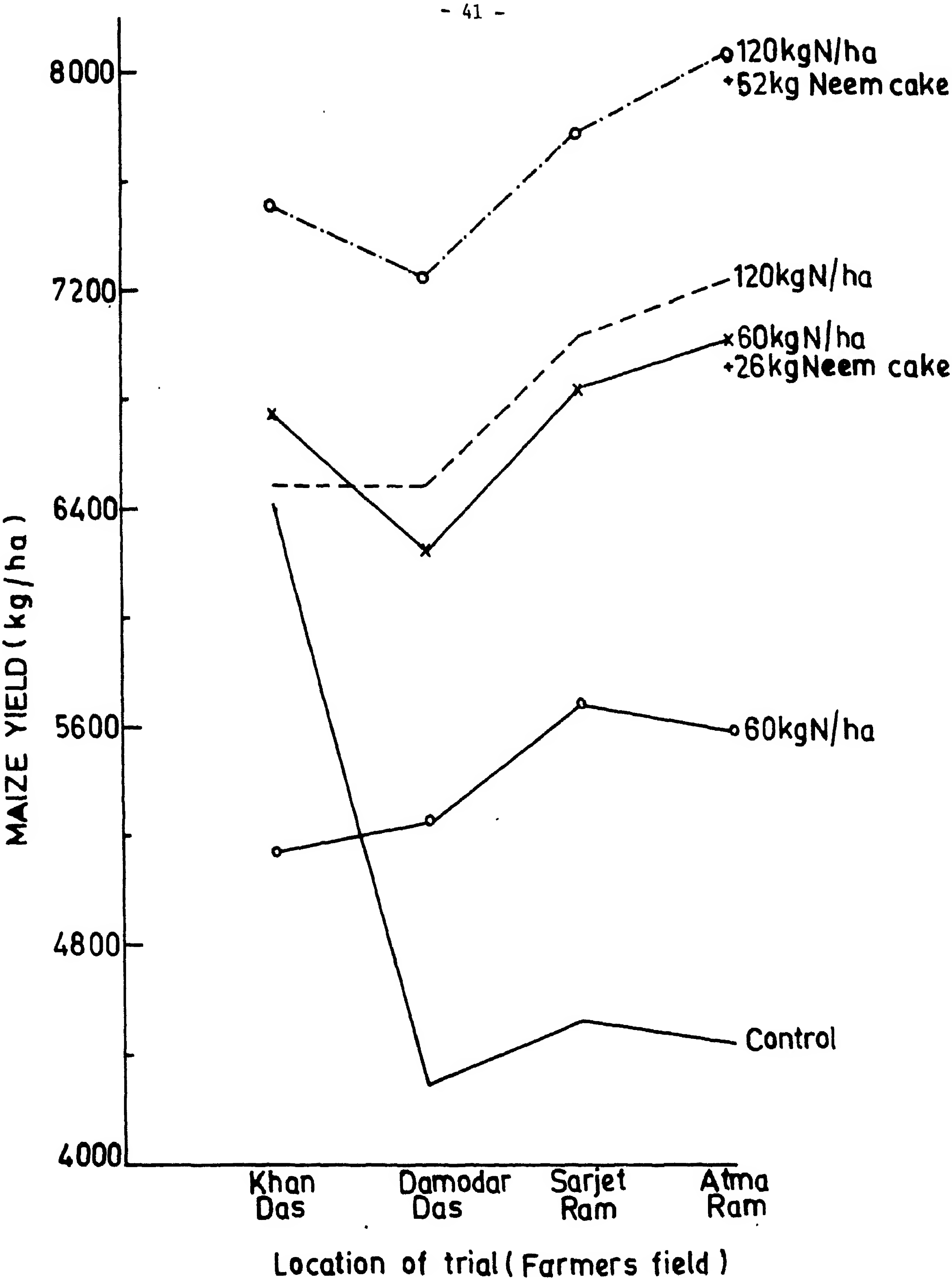

Figure II.28 The effect of neem cake application with nitrogen on maize yield (Ketkar, 1976) One year experiment.

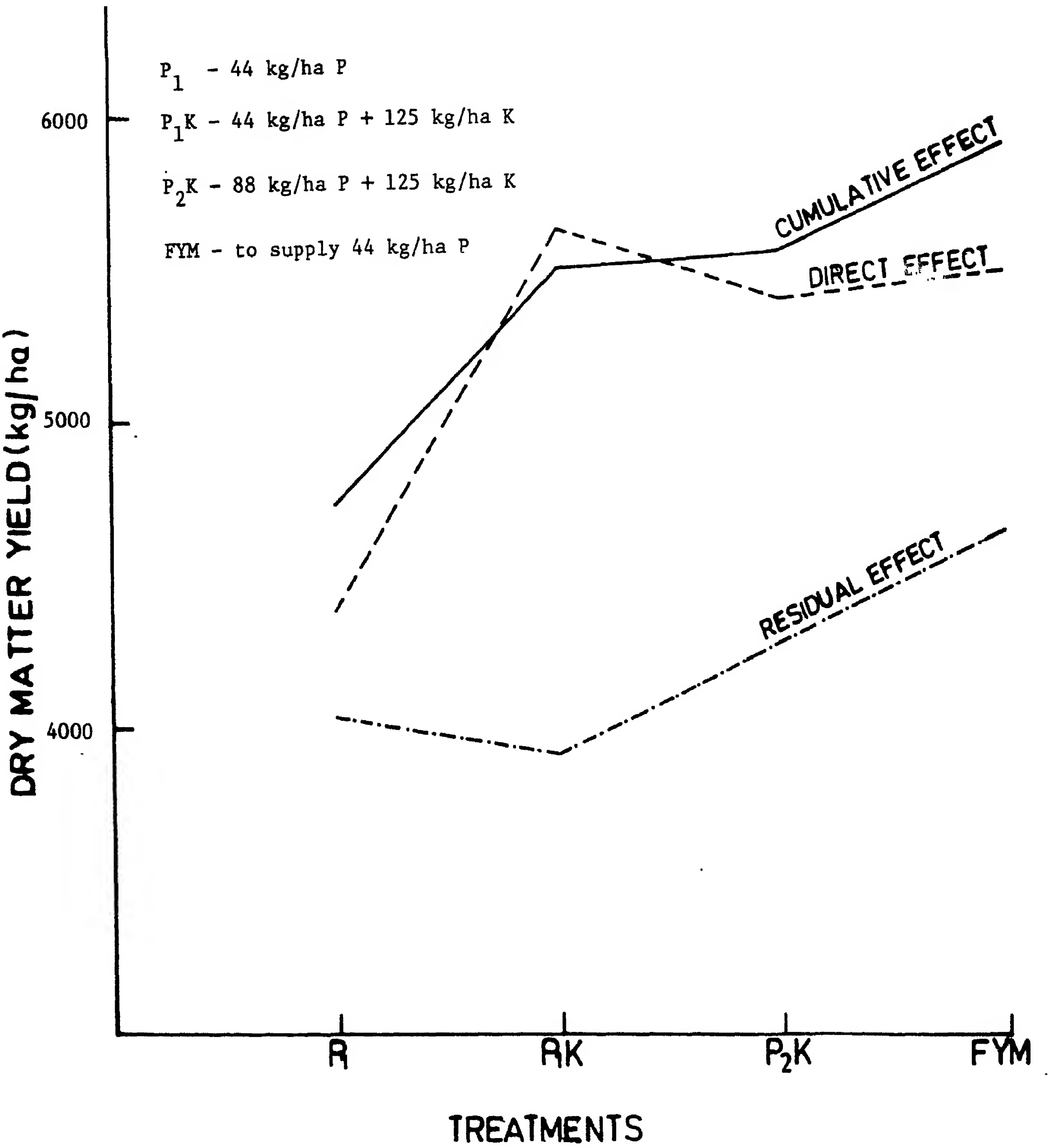

Figure II.29 Direct, residual and cumulative effects of P,K fertilizers and farmyard manure on the dry matter yield of potato tubers (Sharma *et al*,1979). Based on two year's data, 1976-7.

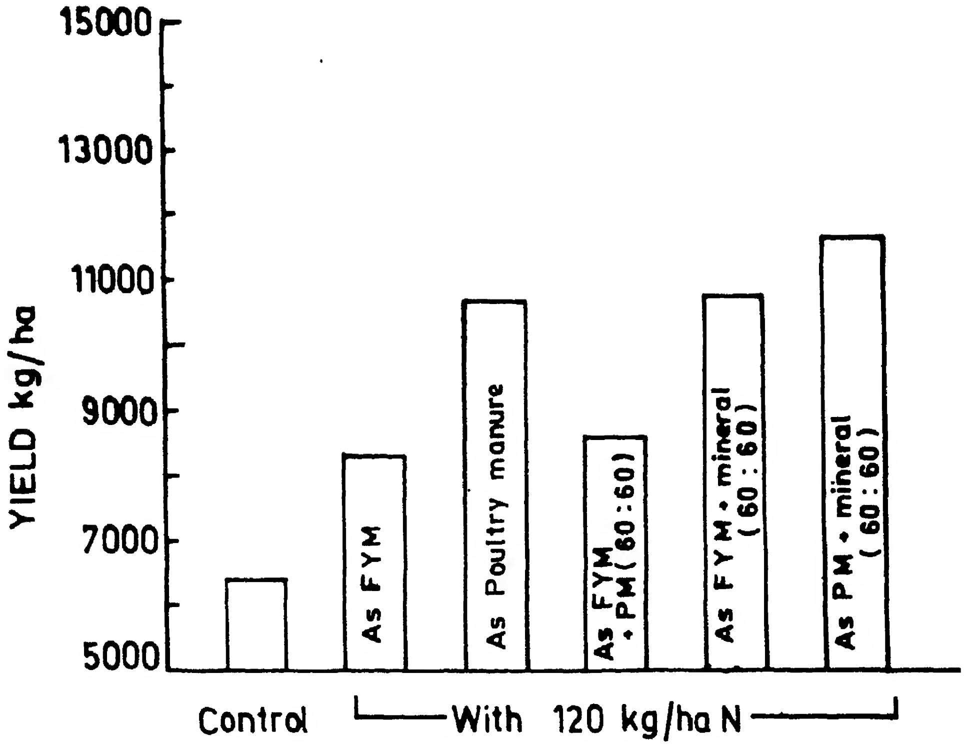

Figure II.30 Effect of poultry and farmyard manures in combination with mineral nitrogen upon potato yield (Singh and Srivastava, 1971) One year experiment.

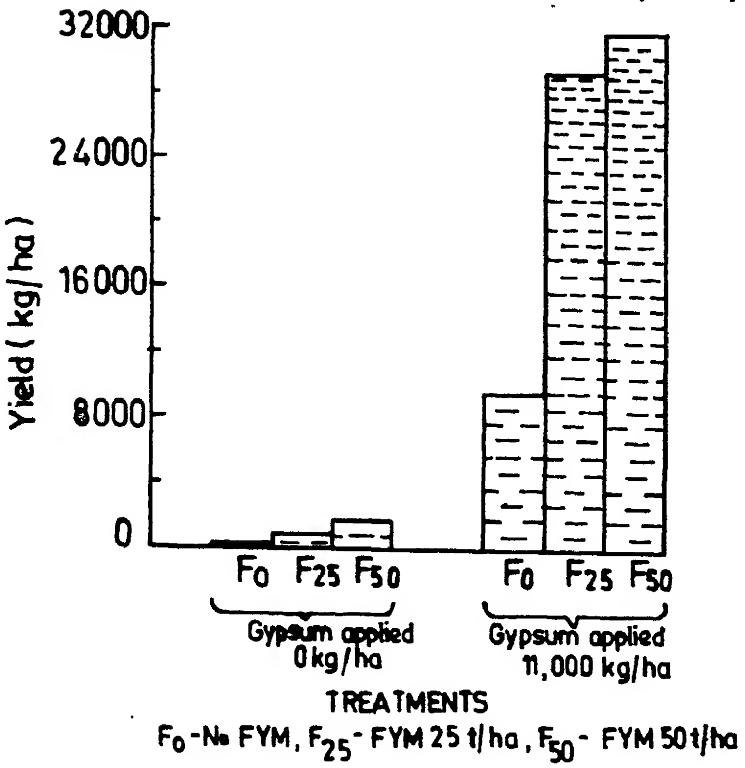

Figure II.31 Yield of fodder (Berseem) as affected by gypsum and farmyard manure application in a sodic soil (Dargan *et al*, 1976). Two year experiment.

Many investigations have been made into the effects of biofertilizers alone or in combination with mineral fertilizers and although some workers have claimed that the use of biofertilizers completely eliminates the need for mineral nitrogen application, the general consensus is that combined use is best. This can be seen clearly from the very positive data shown in Figures II.32 and II.33.

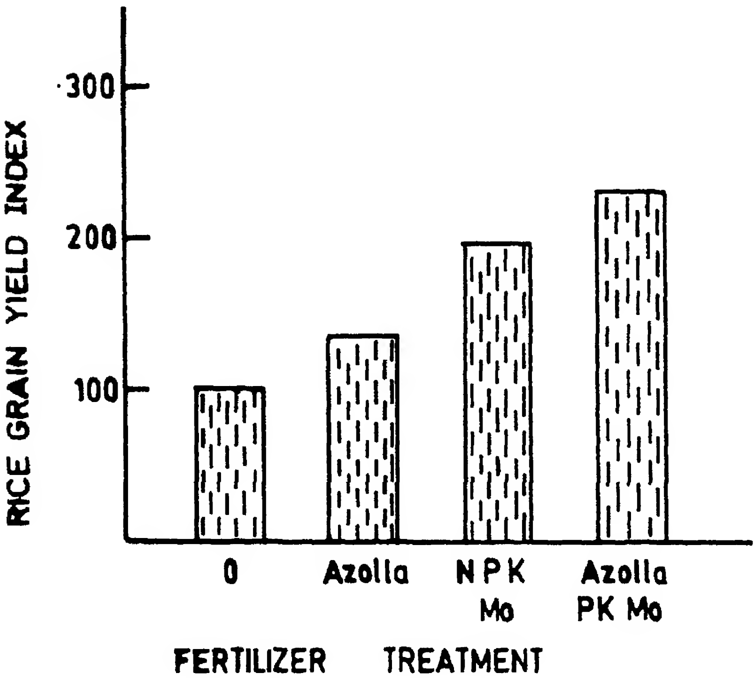

Figure II.32

Effect of Azolla upon rice yield with and without mineral fertilizers (Amarasiri,1978)

One year experiment.

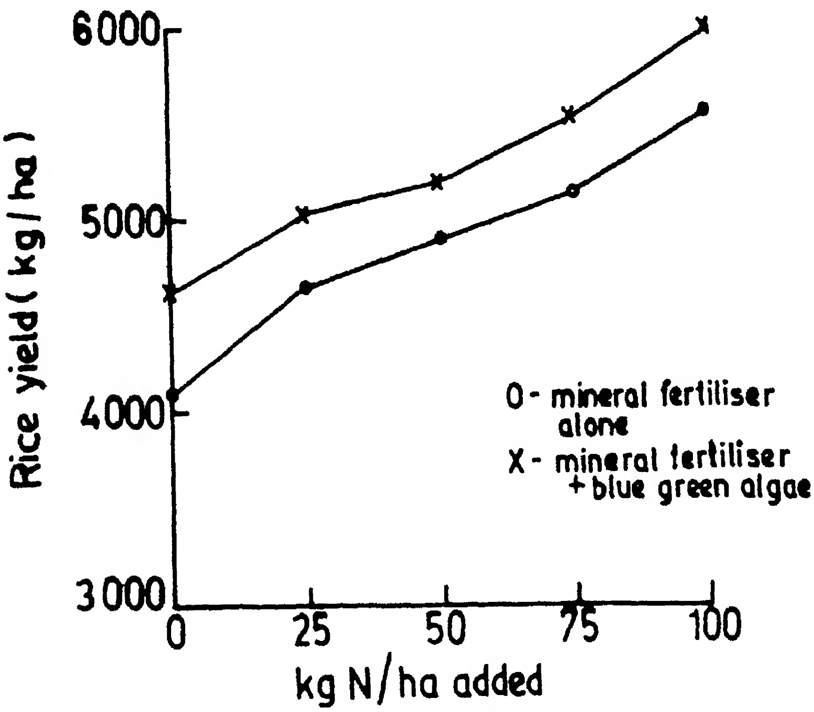

Figure II.33

Effect of blue-green algae upon rice yield with and without minera nitrogen. P and K were provided equally in all treatments (Srnivasan a Ponnayya, 1978)

3 TOXICITY EFFECTS OF DECOMPOSING ORGANIC MATTER

3.1 Toxic effects of decomposing organic manures

Application of manures to soils sometimes causes injury to plants and this can lead to reduction in the potential value of organic manures. Fortunately the toxic effects from decomposing organic materials are short lived as toxins are produced only at certain stages of decomposition and are quickly inactivated in soil.

Plants react to an induced toxicity by lowering their metabolic rate and by building up a resistance and thus plant injury tends to be greater at higher temperatures. Usual symptoms in a plant are shoot growth reduction, some defoliation and a temporary stunting, all caused by partial root destruction. In a short time however, plants recover and, usually, grow better in the organic enriched soil than in a control soil. In Figure II.34 is shown how plants transplanted into a composted soil become stunted at first and then recover to show enhanced growth over the control. It has been shown that this effect is not to be confused with reduced nitrogen availability and effects differ with specific species of plants, different organic manures and different stages of organic matter decomposition.

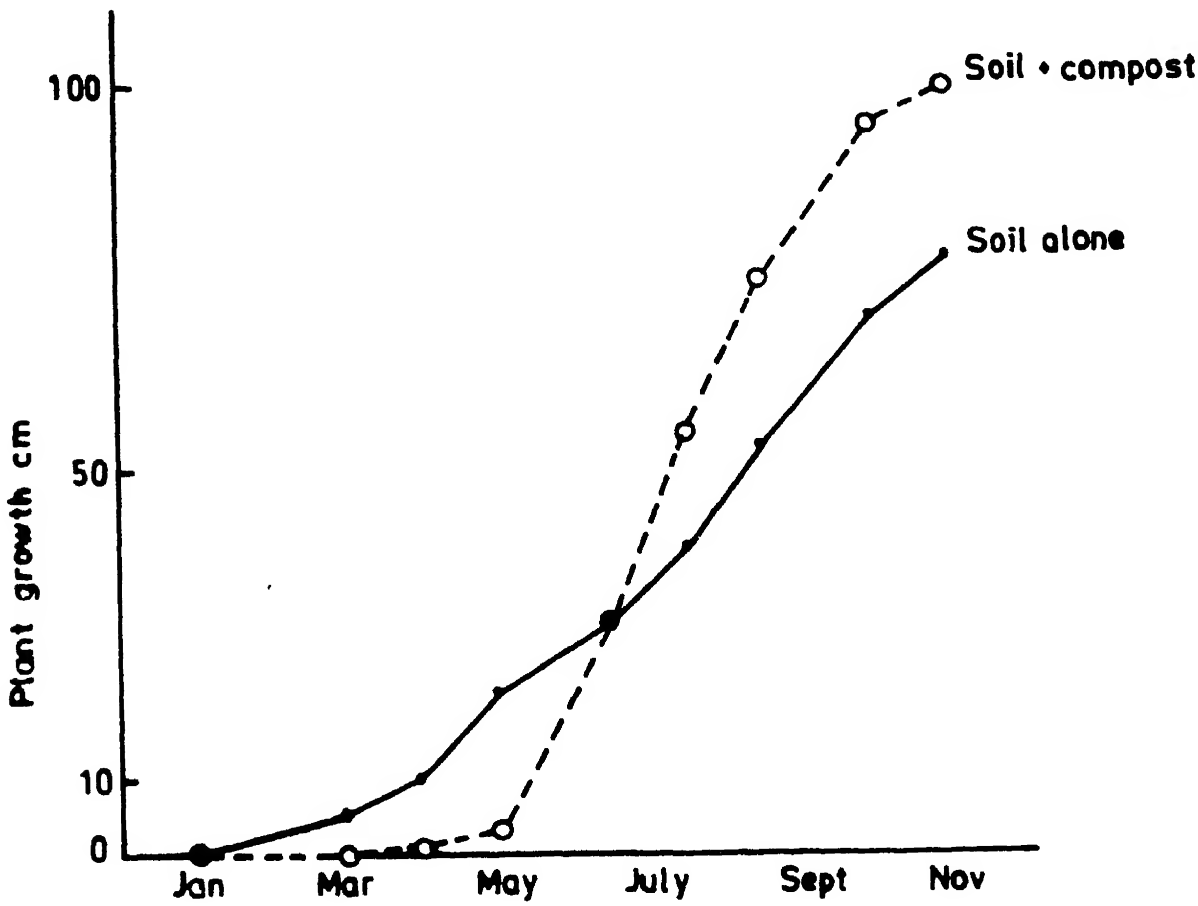

Figure II.34 Effect on plant growth of an organic compost added to soil (Zucconi *et al.* 1981)

PART III

LITERATURE REVIEW

EFFECTS OF APPLICATION OF MINERAL FERTILIZERS AND ORGANIC MANURES UPON SOIL PROPERTIES AND CROP YIELDS

1. Soil Physical Properties

A number of workers (Kibe and Basu 1962; Kanwar and Prihar 1962; Biswas *et al* 1964; Ghosh *et al* 1968; Pharande and Biswas 1968; Biswas and Ali 1969) have shown that organic matter level and structural status of soils can be built up to a certain extent and maintained by judicious application of bulky organic manures. Available research results indicate that continuous use of ammonium sulphate has an adverse effect on structure. Inconsistent results have been obtained with potassium but phosphorus fertilizers have been found to improve soil structure (Biswas *et al* 1964, 1969; Kanwar and Prihar 1962). Although a number of workers have found favourable effects of organic matter on physical properties of soils (Mehta 1951; Uppal 1955; Uppal *et al* 1961), Kanwar and Prihar (1962) observed that farmyard manure was not superior to fertilizers in improving the physical conditions of soils, for example water infiltration, hydraulic conductivity, water holding capacity and aggregation. Biswas *et al* (1971) studied the cumulative effect of different levels of manures and fertilizers on the physical properties of alluvial sandy soils in a permanent manurial trial at Sabour, India. The treatments consisted of inorganic fertilizers alone and in various combinations and farmyard manure at different levels. The organic manure significantly increased the organic matter status of the soils and improved the structural status, water retention and bulk density. There was very little change in the soil properties due to application of inorganics (Table 1).

Gattani *et al* (1976) studied the effect of continuous use of fertilizers and manures on soil physical properties. It was observed that continuous use of farmyard manure helped in maintaining and improving physical properties and organic content of soils. The nitrogenous fertilizers slightly deteriorated soil physical properties but phosphatic fertilizers improved them. It was concluded that if nitrogen fertilizer is used in combination with phosphorus and potassium plus farmyard manure, higher yields can be obtained without causing any deterioration of soil physical properties (table 2).

Table 1. Effects of continuous use of fertilizers and manure on soil physical properties (Biswas *et al* 1971)

Treatment	Structural index	Water retention at tensions 1/10 atm	1/3 atm	15 atm	Hydraulic conduct.	Bulk density
Control (no fertilizer or manure)	34.2	33.4	20.8	5.0	0.50	1.32
A.S. 44.8 kg N/ha	28.0	34.0	19.4	5.4	0.49	1.38
A.C. 44.8 kg N/ha	27.6	33.9	19.4	5.4	0.54	1.48
S.P. 19.7 kg P/ha	49.0	32.3	19.8	5.4	0.43	1.40
KCl 37.2 kg K/ha	35.5	32.4	20.4	5.4	0.43	1.38
P + K	46.4	33.6	21.2	4.9	0.36	1.40
N (A.S.) + P	25.2	33.1	21.4	5.1	0.36	1.40
N (A.C.) + P	22.9	33.1	19.6	4.5	0.47	1.40
N (A.C.) +K	21.7	33.4	20.0	4.7	0.39	1.38
N (A.S.) + K	28.6	34.4	19.9	4.5	0.40	1.43
N (A.S.) + P + K	32.4	33.3	19.6	4.2	0.47	1.35
N (A.C.) + P + K	25.5	33.1	21.0	4.2	0.53	1.45
FYM (69 700 kg/ha/crop)	63.2	49.5	30.4	12.2	0.35	1.30
FYM (17 400 kg/ha/crop)	52.7	38.7	23.3	6.7	0.27	1.34
FYM (17 400 kg/ha/crop)+ N (A.S.)	43.1	38.8	23.3	6.7	0.36	1.27
FYM (69 700 kg/ha/crop) Maize	52.0	42.1	26.2	8.8	0.32	1.32
FYM (69 700 kg/ha every five years	48.0	42.0	22.9	6.3	0.4	1.43
FYM (69 700 kg/ha/crop wheat	51.8	36.9	27.4	9.3	0.26	1.32

A.S. = ammonium sulphate; A.C.= ammonium chloride; S.P.= superphosphate

There was increase in bulk density of soils due to the use of fertilizers whereas where farmyard manure was applied the bulk density remained more or less of the same order as in the control. Increase in bulk density is attributed to the deterioration of soil structure. Similarly for hydraulic conductivity. The percentage of water-stable aggregates greater than 0.25 mm increased strikingly in the manure treatments and increase in water holding capacity was also noticeable.

Table 2 Soil physical properties after five years of continuous manuring and cropping (Gattani *et al* 1976)

Treatment	Bulk density g/cc	Hydraulic conductivity cm/hr	Water stable aggregates >0.25mm %	Water holding capacity %
Control	1.39	5.5	8.3	25.8
N	1.45	6.7	8.6	25.4
P	1.49	6.4	10.7	26.2
K	1.54	6.7	8.2	24.5
NP	1.55	5.7	8.3	26.5
NK	1.42	6.3	7.4	23.4
NPK	1.48	6.0	9.3	25.7
1/2 FYM + 1/2 NPK	1.40	6.0	10.5	27.0
FYM	1.40	5.7	11.9	27.6

Phosphorus treatments did not show any deterioration in regard to water stable aggregates and water holding capacity. A beneficial effect of organic manuring on the physical properties of soils has also been observed by Khanna *et al* (1975) and by Sarkar*et al* (1972).

Different organic materials have different degrees of effect; Kawamura (1966) showed the effect upon soil aggregation of compost as compared with rice straw (Table 3). Rice straw had a greater effect than compost in increasing the percentage of water stable aggregates above 0.25 mm.

Table 3 Comparison of rice straw and compost regarding their effect upon soil aggregation

Organic material	% of soil aggregates			
	18 mesh	18-30	30-50	50-100
None	11.1	14.0	12.5	11.5
Compost (2.25t/ha)	17.1	18.1	14.0	10.9
Rice straw	22.9	19.2	12.2	9.3

2. Physico-chemical properties

2.1 pH value Very little changes in soil reaction as a result of continuous manuring or fertilization have been reported by Singh and Mann (1961) and Kanwar and Prihar (1962). Dayal *et al* (1965) and Das *et al* (1966) observed no effect on pH of soil of continuous application of farmyard manure for five and thirty years respectively. In medium black soils pH was not affected by combined use of farmyard manure and mineral fertilizers as reported by Shinde and Ghosh (1971). Mandal and Pain (1965) observed that use of ammonium sulphate for fifteen years resulted in a decrease in soil pH value. Similar results were

reported by Prasad *et al* (1971) and Venkata Rao and Badiger (1971). Prasad *et al* (1971) working with acid red loam soils of Bihar, India observed that continuous application of nitrogenous fertilizer alone in the form of ammonium sulphate lowered the pH of soil as compared with other treatments. Seasonal addition of organic manure alone or in combination with fertilizer maintained higher pH levels (about 5.8) than treatments receiving fertilizers as NP or NPK. It was concluded that the addition of farmyard manure had a buffering effect and improved soil pH (Table 4).

Table 4 Effect of continuous application of manure and fertilizers on soil pH (Prasad *et al* 1971)

Treatment	1964-5 maize	1965-66 maize	1963-64 maize	1964-65 wheat	1965-66 wheat
N_o, manure, no lime	5.0	5.5	5.6	5.2	5.7
N_{44} as AS every season	4.5	4.6	4.5	4.8	4.7
N_{44} + $P_{19.4}$ as SP	5.5	5.7	5.4	5.3	5.5
N_{44} + $P_{19.4}$ + $K_{36.5}$ as KCl	5.2	5.5	5.2	5.2	5.0
FYM (44 kg N)	5.8	5.9	6.1	5.9	5.8
FYM + $P_{19.4}$	5.9	5.9	5.9	6.2	5.9
FYM + $P_{19.4}$ + $K_{36.5}$	5.4	5.6	5.8	5.9	5.8
Lime + N_{44} + $P_{19.4}$ + $K_{36.5}$	6.6	6.4	6.6	5.5	6.4
Lime + FYM + $P_{19.4}$ + $K_{36.5}$	6.8	6.6	6.8	6.8	6.6

AS = ammonium sulphate; SP = superphosphate

2.2 Cation exchange capacity Bandopadhyay *et al* (1969) found that the cation exchange capacity of soil was increased by compost and that there was no effect by nitrogenous fertilizers. However, in salt affected soils, Chauhan *et al* (1973) found increased cation exchange capacity with application of farmyard manure. Sandhu and Meelu (1974) reported that cation exchange capacity was increased significantly only by continuous application of manure. In permanent manurial experiments, Kanwar and Prihar (1962) observed that continuous use of farmyard manure and fertilizers increased the cation exchange capacity of soils. Mandal and Pain (1965) also reported that compost, cow dung and mustard cake increased soil cation exchange capacity. Lavti *et al* (1969) reported a significant positive correlation between organic matter content and cation exchange capacity of soils in Rajasthan, India. Maurya and Ghosh

(1972) observed considerable increase in C.E.C. of soils under green manuring and phosphate fertilization followed by green manuring in a legume rotation. They also noticed a significant effect of farmyard manure upon the exchange capacity. Maximum increase was found with rape cake. Chemical fertilizers were found to generally cause a moderate rise in exchange capacity. Swarup and Ghosh (1979) studied the effect of intensive manuring on soil properties and found that application of farmyard manure increased cation exchange capacity. Application of chemical fertilizers only resulted in small changes in exchange capacity.

2.3 Organic carbon Acharya and Rajagopalan (1956) reported that continuous application of farmyard manure at various levels over a period of up to forty five years, increased the carbon content of the soil by about forty percent over the unmanured check plot. There was no significant increase in carbon in plots which received mineral fertilizers. Kanwar and Prihar (1962) noted that continuous application of organic manure and mineral fertilizers maintained soil organic carbon at a higher level than in check plots. Singh and Mahant (1968) found that in an acid red clay loam application of farmyard manure increased organic carbon. Significant increase in organic carbon due to manure was also reported by Vig and Bhumbla (1970) who also found that nitrogenous, phosphatic and potassic fertilizers increased the carbon content. Prasad *et al* (1971) found that farmyard manure alone or with phosphorus or potassium increased soil organic carbon. Sandhu and Meelu (1974) observed that organic carbon can be increased by continuous application of farmyard manure and similar results were reported by Naphade and Bhoyar (1975) and by Ruhal and Shukla (1978). Chaudhuri and Vachhani (1965) found that the carbon content of soil remained unchanged with the continuous application of ammonium sulphate for ten years. Similar results were reported by Mandal and Pain (1965) and Bandopadhyay *et al* (1969). Shinde and Ghosh (1971) observed a significant increase in the soil organic matter content in the top 15 cm layer with farmyard manure application (Table 5). However, the actual extent of increase over the control plots has not been of very high order. Since organic matter is decomposed rapidly it has not been possible to achieve its build up, even in experimental trials (Sannyasi Raju 1952). The influence of nitrogen fertilization tending to increase soil organic carbon (in any case not very significantly) was attributed to greater quantities of crop residues being left after harvest (Acharya and Rajgopalan 1956). Maurya and Ghosh (1972) reported that continuous use of farmyard manure (at 9 000 kg/ha) resulted in high content of organic matter in comparison with control plots and those with other treatments. The next most effective treatment was green manuring with phosphorus fertilizers. The continuous use of balanced doses of chemical fertilizers was not found to cause damage to soil organic matter in the long run. Nitrogen and phosphorus combinations gave increases in organic matter over the control but not to the extent given by manure with and without phosphorus. Swarup and Ghosh (1979) studied the effect of manuring in a long term experiment involving various levels of fertilizers and combinations of fertilizers with manures. After harvest of the wheat crop, all treatments except that of nitrogen alone, had significantly increased soil organic carbon over the control. There was a significant increase in organic carbon in the N plus P treatment compared with N alone. Farmyard manure with 100% NPK brought about some improvement in soil organic carbon but not significantly more than 100% NPK alone.

Table 5 Effect of fertilizers and manure on the organic matter content of soil - 0-15 cm layer (Shinde and Ghosh, 1971)

Treatment (dose/ha)		Organic matter %
F_o	No FYM	1.07
F_1	FYM 5600 kg	1.15
N_o	No nitrogen	1.10
N_1	33.6 kg N	1.11
N_2	67.2 kg N	1.12
P_o	No phosphorus	1.14
P_1	14.78 kg P	1.10
P_2	29.57 kg P	1.09
K_o	No potassium	1.13
K_1	27.9 kg K	1.07
K_2	55.8 kg K	1.12

Table 6 Organic carbon status of soil as affected by fertilizer and manure (Maurya and Ghosh, 1972)

Treatment kg/ha	Organic Carbon %	
	Old manurial experiment (mean of series A and B)	New manurial experiment (Mean of ten replicates)
FYM at 8 960	0.467	0.526
FYM at 4 480	0.387	-
Rape cake - 44.8 N	0.325	0.376
FYM at 4 480 + rape cake 22.4N	0.400	-
N (44.8) as AS	0.284	0.364
P (39.4) as SP	0.363	0.362
K (46.5) as potassium sulphate	0.332	0.336
N + P	0.341	0.375
P + K	0.410	0.331
N + K	0.337	0.344
N + P + K	0.400	0.374
Green manure, cereal rotation	0.380	-
Green manure, legume rotation	0.452	-
Green manure + P	0.506	-
No green manure, no legume	0.329	-
No manure	0.326	-

2.4 Total Nitrogen Ghosh and Kanzaria (1962) from a long term experiment on calcareous soils with continuous cropping reported that mineral nitrogen and phosphorus did not improve the nitrogen content of the soil as was done by farmyard manure. Kanwar and Prihar (1962) found that regular application of farmyard manure with mineral fertilizer maintained the nitrogen content of soils at higher levels than in untreated plots. Vig and Bhumbla (1970) reported that bulky organic manures and/or mineral N and P, increased total soil nitrogen content. Sandhu and Meelu (1974) from a long term application of farmyard manure in a non-saline sandy loam concluded that total nitrogen is increased. Shinde and Ghosh (1971) studied the effect of continuous manuring on a medium black soil. The treatments consisted of FYM with various levels of NPK and no significant results were obtained. Maurya and Ghosh (1972) while studying the effect of long term manuring on alluvial calcareous soils in Pusa (North Bihar, India) observed that FYM and green manuring with phosphate resulted in higher contents of soil nitrogen (Table 7).

Table 7 Effect of manure and fertilizers upon soil total nitrogen (Maurya and Ghosh, 1972)

Treatment kg/ha	Total N % Old manurial experiment (Mean of series A and B)	New manurial experiment (Mean of ten replicates)
FYM at 8 960	0.053	0.057
FYM at 4 480	0.047	-
Rape cake at 44.8 N	0.042	0.042
FYM + rape cake	0.048	-
N (44.8)	0.045	0.041
P (39.4)	0.042	0.041
K (46.5)	0.037	0.039
N + P	0.047	0.045
P + K	0.045	0.040
N + K	0.041	0.041
N + P + K	0.045	0.043
Green manuring, cereal rortation	0.047	-
Green manuring, legume rotation	0.044	-
Green manuring + P	0.047	-
No green manure, no legume	0.034	-
No manure	0.036	-

Whereas in the plots receiving 9 000 kg/ha of FYM the total nitrogen was 0.053%, the plots receiving FYM and rape cake and those with green manure and phosphorus had 0.048 and 0.047. Swarup and Ghosh (1979) in a long term experiment at New Delhi observed that plots receiving FYM and 100% NPK had the highest nitrogen content (0.068%), (Table 8). With an increase in the graded dose of NPK (150% of the optimum) the nitrogen content increased and this was attributed to the higher amount of nitrogen applied. Sahu and Nayak (1971) studied the effect of continuous application of ammonium sulphate alone and in combination with organic manure for ten years (Table 9) and reported an appreciable increase in total soil nitrogen with the manurial treatments. The highest increase was with farmyard manure alone (0.058%) or in combination with ammonium sulphate (0.060%).

Table 8 Effect of fertilizers and manure on total nitrogen in soils (Swarup and Ghosh, 1979)

Treatment	Total N % (1973) Before pearl millet	After wheat (1974-5)
50% optimum NPK	0.064	0.065
100 % optimum NPK	0.063	0.068
150 % optimum NPK	0.064	0.071
100 % optimum NPK and handweeding	0.064	0.069
100 % optimum NPK + Zn	0.067	0.069
N + P	0.066	0.068
N	0.065	0.065
100% optimum NPK + FYM	0.066	0.073
100% optimum NPK + S	0.065	0.069
Control	0.064	0.060

Table 9 Effect of continuous application of manure and fertilizer on soil nitrogen (Sahu and Nayak, 1971)

Treatment kg/ha	Total N %
At start of trial, 1956	0.029
At end of tenth year, 1965	
No manure (control)	0.021
Organic manures (45 kg/ha N)	
FYM	0.058
Green manure	0.054
Groundnut cake	0.050
Ammonium sulphate	
N 22.5 kg/ha	0.032
45.0 kg/ha	0.037
67.5 kg/ha	0.045
90.0 kg/ha	0.054

2.5 Carbon-Nitrogen Ratio Ghosh and Kanzaria (1962) during a study on calcareous soil observed that heavy doses of farmyard manure widen the soil C/N ratio. Bhandari *et al* (1972) found that during an incubation of 105 days the C/N ratio of soils was decreased wherever dung was used as manure. Shinde and Ghosh (1971) found that with application of farmyard manure the ratio widened due to accumulation of organic matter; application of phosphate enhanced the soil nitrogen and thus reduced the C/N ratio. Swarup and Ghosh (1979) observed that since nitrogen had little influence on organic carbon, its single application gave the lowest C/N ratio (Table 10). In the study however, application of farmyard manure in combination with NPK was not found to increase the C/N ratio, probably because of an increase simultaneously of soil nitrogen.

Table 10 Effect of manure and fertilizers upon soil C/N ratio (Swarup and Ghosh, 1979)

Treatment	C/N ratio	
	Before millet, 1973	After wheat, 1974-5
50% optimum NPK	6.9	7.4
100% optimum NPK	7.5	7.6
150% optimum NPK	7.4	7.2
100% optimum NPK + hand weeding	7.1	7.4
100% optimum NPK + Zn	7.0	7.3
N + P	6.6	6.2
N	6.5	6.2
100% optimum NPK + FYM	6.7	7.6
100% optimum NPK + S	6.6	7.1
Control	6.5	6.5

2.6 Available plant nutrients

2.6.1 Available nitrogen Kanwar and Prihar (1962) reported that continuous application of farmyard manure maintained available nitrogen in soil at a higher level than in the control. They also reported that the use of mineral fertilizers was effective in maintaining available nitrogen. Similar results have been given by Mandal and Pain (1965) and Singh and Verma (1969). Debnath and Hajra (1972) found from incubation studies that available nitrogen is increased by farmyard manure and Ruhal and Shukla (1978) recorded increased available nitrogen in a soil after ten years manuring with farmyard manure whereas mineral nitrogen fertilizers had not made any significant change. Singh and Srivastava (1971) studied the effects of organic manure and mineral fertilizers upon the mineralization of nitrogen in a sandy loam soil (Table 11).

Table 11 Effect of organic manure and mineral fertilizer upon soil nitrogen mineralization (Singh and Srivastava, 1971)

Treatment	Available N ppm (after days of incubation)						
	7	15	30	45	60	75	90
Fertilizer N	199	203	215	245	274	302	329
Fertilizer N + FYM	56	7	65	111	139	175	224
Fertilizer N + poultry manure	99	70	122	172	199	237	276

Fertilizer nitrogen was found to be immobilised with the addition of organic manures (Table 12). The results reveal that a large amount of fertilizer nitrogen is stabilized when it is applied in combination with manures and is subsequently released to meet the requirement of the next crop. It was concluded that combining the use of manures and fertilizers is a good way of avoiding losses of nitrogen by leaching and volatilization.

Puranik *et al* (1978) studied the effect of long term manuring and fertilizing in vertisols upon the distribution of various forms of nitrogen. Addition of

Table 12 Amounts of nitrogen immobilized by the addition to a soil of organic manures (Singh and Srivastava,1971)

Treatment	N ppm immobilized at various days interval						
	7	15	30	45	60	75	90
Fertilizer N + FYM	100	133	93	74	75	65	53
Fertilizer N + poultry Manure	143	196	150	135	135	127	105

farmyard manure had a pronounced influence in increasing total and organic nitrogen contents and green manuring yielded a greater amount of nitrate nitrogen as compared to NPK treatment (Table 13).

Table 13 Distribution of nitrogen as affected by long term manuring and fertilization (8 years). (Puranik *et al*,1978)

Treatment	N fractions (mg N/100g soil on oven-dry basis) at 23 cm			
	NH_4-N	NO_3-N	Fixed NH_4-N	Total N
Control	1.4	2.8	5.2	70.0
FYM	1.4	1.9	10.3	112.2
NPK	1.9	2.8	4.5	70.0
FYM + Green manure	4.4	6.4	7.0	105.1

2.6.2 Available phosphorus Continuous application of farmyard manure and castor cake for four years increased the availability of soil phosphorus (Singh and Mann,1961). Datta and Goswami (1962) observed in both culture and laboratory studies that availability of phosphorus in a soil increased with increase in organic matter levels. Kanwar and Prihar (1962) and Havangi and Mann (1970) observed that continuous application of farmyard manure built up the available phosphorus reserves in soil. Singh and Parkash (1968) found that organic matter undergoes slow oxidation, producing acids which increased the availability of phosphorus. Kahn *et al* (1962) reported a decrease in available phosphorus when farmyard manure was applied to a non-calcareous soil. Bhat and Bouyer (1968) found that with a ferruginous tropical soil of low organic matter, addition of manure increased the solubility of phosphorus. Prasad *et al* (1971) found that application of farmyard manure alone or with phosphorus and potassium increased the available phosphorus in a soil. Sandhu and Meelu (1974) reported that continuous application of manures significantly increased the available phosphorus and Ruhal and Shukla (1978) observed increases in available phosphorus due to farmyard manure but decreases due to mineral nitrogen application in a long term trial. Shinde and Ghosh (1971) in a long term manurial experiment observed that farmyard manure gave a considerable increase in available phosphorus (Table 14), which may be explained on the basis

Table 14 Effect of fertilizers and manure upon available phosphorus in soil (Shinde and Ghosh, 1971)

Treatment (dose/ha)		Available P (kg/ha)
F_o	No FYM	21.38
F_1	FYM 5 600 kg	26.09
N_o	No nitrogen	22.21
N_1	33.6 kg N	23.94
N_2	67.2 kg N	24.90
P_o	No phosphorus	20.94
P_1	14.8 kg P	24.11
P_2	29.6 kg P	26.13
K_o	No potassium	24.64
K_1	27.9 kg K	22.66
K_2	55.8 kg K	24.37

of larger production of carbon dioxide having a solubilizing effect on soil phosphates and the production of organic anions which on one hand retard the fixation of phosphorus by aluminium and iron and on the other, solubilise already fixed iron and aluminium phosphates. In the case of superphosphate application an increase of 14 % and 25% over no phosphate was observed in the P_1 and P_2 treatments respectively. Nitrogen and potassium fertilizers were ineffective in bringing about changes in soil available phosphorus. Maurya and Ghosh (1972) noticed significant increases in available phosphorus in a soil due to use of farmyard manure and phosphatic fertilizers. Prasad *et al* (1971) studied the effect of continuous application of manure and fertilizer on the available phosphorus in acid soils of Bihar, India and observed that the plots receiving only nitrogenous fertilizers gave the lowest value and organic manure supplemented with inorganic fertilizer and lime (Lime + FYM + PK), the highest values, their respective averages being 5.4 and 49.0 ppm. In general, lime and organic manure were found to result in better release of phosphorus (Table 15). Singh and Ram (1977) found that addition of organic manure to alluvial and laterite soils increased the proportion of saloid phosphorus and lowered the conversion of added phosphorus into aluminium, iron and calcium phosphates. The experiments conducted on Bangkhen and Rangsit clay soils in Thailand reveal that pH and organic matter content did not change as a result of different organic manures or mineral fertilizers but the continuous application of city waste compost for four years alone or in combination with mineral fertilizers showed an increase in available phosphorus and potassium. The application of city compost or animal manure with and without mineral fertilizer helped in building up soil fertility (Table 16).

Table 15. Effects of continuous application of manure and fertilizers upon available phosphorus in a soil (Prasad *et al* 1971)

Treatment kg/ha	1964-65 Kharif	1965-66 Kharif	1963-64 Rabi	1964-65 Rabi	1965-66 Rabi	Mean of seasons
No manure, no lime	5.0	6.0	6.0	7.0	8.0	6.4
N_{44} as AS every season	5.0	5.0	5.0	6.0	6.0	5.4
$N_{44} + P_{19.4}$ as SP	41.0	43.0	41.0	38.0	39.0	40.4
$N_{44} + P_{19.4} + K_{36.5}$	28.0	23.0	25.0	26.0	29.0	26.2
FYM (44 kg N)	36.0	36.0	31.0	27.0	33.0	32.6
FYM + $P_{19.4}$	43.0	39.0	34.0	31.0	36.0	36.6
FYM + $P_{19.4} + K_{36.5}$	23.0	22.0	17.0	17.0	19.0	19.6
Lime + $N_{44} + P_{19.4} + K_{36.5}$	27.0	28.0	21.0	31.0	23.0	26.0
Lime + FYM +P + K	54.0	54.0	50.0	43.0	45.0	49.0

2.6.3 Available potassium Kanwar and Prihar (1962) and Sahu and Nayak (1971) observed that continuous application of organic manure increased the available potassium in a soil. Maurya and Ghosh (1972) reported that a small increase in exchangeable potassium with continuous application of farmyard manure was found to be statistically significant in the New Pusa (India) permanent manurial experiment. Depletion of the potassium content of a soil with continuous nitrogen and phosphorus treatment was observed by Sundra Rao and Krishnan (1963), whereas Maurya and Ghosh reported that continuous use of mineral fertilizers increased available potassium in a soil. Soundarajan (1962) found that application of cattle manure did not affect exchangeable potassium in soil but Sandhu and Meelu (1974) in a long term experiment found that farmyard application increased available potassium significantly. Naphade and Bhoyar (1975) studied five levels of manure and manure plus NPK and found that available potassium content in the soil increased with the higher levels. Ruhal and Shukla (1978) concluded from a permanent manurial trial that available potassium increased significantly with farmyard manure but decreased if only mineral nitrogen fertilizers were used. Shinde and Ghosh (1971) did not observe any significant difference in exchangeable potassium in soil during a long term manurial experiment. Biswas *et al* (1977) studied the accumulation and decline of available phosphorus and potassium in a soil under multiple cropping. Use of farmyard manure in conjunction with 100% optimum NPK led to a greater accumulation of available phosphorus than in the NPK treatment alone. Available potassium did not increase substantially at higher rates of potassium fertilization; more accumulation was found with FYM and NPK treatment (Table 17). Grewal and Sharma (1981) observed that continuous use of phosphorus alone invariably increased exchangeable potassium in alluvial soils but led to a

Table 16 Chemical analysis of soils after continuously applying city waste compost and farmyard manure with and without mineral fertilizers for four years (Jugsiyinda *et al* , 1978)

		pH		% Org.Mtr.		Avail.P ppm		Avail.K ppm	
		BKN	RST	BKN	RST	BKN	RST	BKN	RST
Control		5.0	4.2	3.3	5.0	6.6	25.5	130.3	53.8
City compost	1 875 kg/ha	5.1	4.3	3.3	5.0	5.8	28.9	122.7	64.7
City compost	3 125 kg/ha	5.2	4.2	3.4	5.1	6.7	34.6	128.7	64.3
City compost	6 250 kg/ha	5.1	4.3	3.4	5.3	11.1	46.9	134.4	64.7
Manure	1 875 kg/ha	5.0	4.4	3.4	4.9	5.8	27.6	128.5	67.9
Manure	3 125 kg/ha	5.1	4.3	3.3	5.3	5.0	27.1	129.9	70.6
Manure	6 250 kg/ha	5.1	4.3	3.3	5.1	5.2	24.9	131.1	74.8
City compost	1 875 kg/ha + NPK	5.1	4.3	3.1	5.1	8.2	32.7	128.0	59.5
	3 125 kg/ha + NPK	5.1	4.3	3.3	5.3	7.5	46.8	125.1	61.6
	6 250 kg/ha + NPK	5.1	4.4	3.1	5.7	10.9	56.5	125.4	63.3
Manure	1 875 kg/ha + NPK	5.0	4.3	3.4	5.5	5.9	29.5	122.6	58.9
	3 125 kg/ha + NPK	5.2	4.3	3.3	5.2	5.0	30.7	127.3	76.2
	6 250 kg/ha + NPK	5.0	4.2	3.5	5.2	6.9	31.3	126.1	75.2
NPK		5.1	4.2	3.4	5.1	5.2	27.8	116.7	63.6

BKN = Bangkhen

RST = Rangsit

Table 17 Effect of continuous application of fertilizers and manure on the P and K status of a loamy sand soil after two cycles of crop rotation (Biswas *et al*, 1977)

Treatment	Available P (kg/ha)		Available K (kg/ha)	
	Start	After 2 cycles of crop rotation	Start	After 2 cycles of crop rotation
Control	8.8	2.1	100.0	72.5
100% optimum N	7.0	2.8	89.0	70.0
100% optimum NP	7.0	29.5	89.0	62.1
100% optimum NPK	8.6	28.4	96.0	111.4
100% optimum NPK + FYM	8.0	42.2	97.5	124.0
50 % optimum NPK	8.1	18.5	101.0	95.4
150% optimum NPK	8.0	37.0	92.5	127.1

Table 18 Effect of manuring on soil fertility in a long term experiment at Jullundur, India (Grewal and Sharma,1981)

Treatment	Soil Fertility		
	Org.C %	Available P ppm	Available K ppm
Control	0.26	3.7	53.4
44 kg/ha P	0.34	12.2	71.5
44 kg/ha P + 83 kg/ha K	0.34	14.6	112.4
FYM (44 kg/ha P)	0.64	20.4	140.3

potassium depletion in hill soils (Table 18). Higher rates of nitrogen tended to deplete exchangeable potassium in soil but had little effect on available phosphorus. Application of phosphorus resulted in its accumulation in the soils and continued application at a higher rate of phosphorus depleted organic carbon and nitrogen in acid hill soils. Farmyard manure applied to supply 44 kg/ha of phosphorus was more effective in enriching the soils with available phosphorus and potassium than 44 kg/ha of phosphorus and 83 kg/ha of potassium as mineral fertilizer.

Ghosh (1981) summarised the data regarding fertility status of soils after continuous cropping and manuring at the Pusa (India) permanent manurial experiments (Table 19). Farmyard manure had the best effect on the fertility status of soils. It was also observed that balanced application of mineral fertilizers did not reduce land productivity.

Table 19 Fertility status of a soil after 18 years of continuous cropping and manuring in the Pusa Permanent Manurial Trials (Ghosh, 1981)

Treatment	Organic carbon %	Available P kg/ha	Available K kg/ha
Manuring in legume cropping system			
FYM (9000 kg/ha)	0.47	16.3	143
NPK (45-39.6-46.5)	0.40	14.8	128
NP (45-39.6)	0.34	20.4	110
N (45)	0.28	8.2	100

2.6.4 Available micronutrients Maurya and Ghosh (1972) observed that application of farmyard manure resulted in an increase in soil exchangeable manganese. No significant change was observed with other treatments consisting of various levels of NPK.

Field trials carried out under the All India Coordinated Rice Improvement Project (ICAR) revealed that high doses of nitrogen contribute to zinc deficiency (AICRIP, 1971). The adverse affect is attributed to retention of zinc in plant roots as a complex with protein.

Mineral nitrogen sources can influence soil pH and those which increase acidity are expected to enhance the availability of micronutrients. Decline in available zinc has been reported as a result of heavy fertilization with phosphorus (Hulagur *et al*, 1975; Sharma and Meelu, 1975). Treatments with organic manures have, by and large, improved the availability of several micronutrients (Table 20).

Most of mineral fertilizers are pure chemical compounds and contain small quantities of micronutrient elements whereas organic manures are a potential source. Katyal and Sharma (1979) have compiled information regarding the micronutrient content of different manures (Table 21).

Table 20 The effect of organic manures upon micronutrient availability in soil (Katyal and Sharma, 1979)

Manure	Influence on micronutrient availability			
	Zn	Fe	Mn	Cu
FYM	0	0	-	0
FYM	-	nd	nd	nd
FYM	+	nd	nd	nd
FYM	+	nd	nd	nd
Poultry manure	+	+	nd	nd
City waste compost	+	nd	nd	+
Rural compost	+	nd	nd	+
Cattle feedlot manure	+	+	+	+
FYM	+	+	+	+

+ Increased, - decreased, 0 no effect, nd not determined

Table 21 Micro-nutrient content of different organic manures (Katyal and Sharma, 1979)

Manure	Zn	Cu	Mn	Fe
		ppm		
FYM	120	62	410	-
Cow dung	210	61	150	-
Goat dung manure	2570	1925	6420	-
Poultry manure	70	8	191	1280
Goat droppings	62	13	171	4980
Poultry manure	50	69	190	1075
FYM	57	-	250	2600
Pig manure	198	13	168	1600
Pressmud	94	-	450	1140
Rice straw	20	-	340	280
Sugar cane bagasse	17	-	15	240
Castor cake meal	76	-	50	590

3 Microbial Properties of Soil

Venkata Rao *et al* (1972) studied the changes in microbiological properties of red soils as a result of heavy fertilization. Addition of increasing amounts of nitrogen generally increased the population of bacteria and fungi appreciably but inhibited that of nitrogen fixing Azotobacter. Application of phosphorus increased the microbial population except phosphobacteria (Tables 22 and 23).

Table 22 Effect of repeated applications over a period of 33 months of different amounts of nitrogen on soil microflora (expressed as 10^x per gramme of moisture free soil). Venkata Rao *et al*, 1972

Microorganism	Treatment				
	C	N_o	N_1	N_2	N_3
Bacteria (10^6)	13.64	25.60	145.0	43.80	35.70
Actinomycetes (10^6)	0.16	1.74	2.5	3.81	0.71
Fungi (10^4)	3.02	7.08	10.85	14.23	17.18
Azotobacter (10^2)	21.50	21.49	1.47	0.62	0.21

C = control, N_o = 0 N/ha, N_1 = 45 kgN/ha, N_2 = 90 kgN/ha, N_3 = 180 kgN/h
All treatments received 19.8 kg P/ha and 37.3 kg K/ha.

Table 23 Effect of repeated applications over a period of 30 months of different amounts of superphosphate on soil microflora (expressed as 10^x per gramme of moisture free soil) Venkata Rao *et al*, 1972.

Microorganism	Treatment					
	C	P_o	P_1	P_2	P_3	P_4
Bacteria (10^6)	13.64	77.10	45.60	52.30	168.70	61.80
Actinomycetes (10^6)	0.16	0.62	0.86	0.76	7.95	0.55
Fungi (10^4)	3.02	7.30	7.44	5.79	11.54	1.39
Phosphobacteria (10^2)	0.00	0.88	0.10	0.00	0.00	0.00

C = control, P_o = 0 P/ha, P_1 = 37.3 kg P/ha, P_2 = 75.6 kg P/ha, P_3 = 149.2 kg P/ha, P_4 = 298.4 kg P/ha. All treatments received 67.5 kg N/ha and 37.3 kg K/ha.

4. Crop Yield

4.1 General

The role of bulky organic manures in improving land productivity has been shown by many long term experiments (Kalamkar and Sirpal Singh, 1935; Basu and Kibe, 1943; Sundra Rao and Krishnan, 1963; Maurya and Ghosh 1972). Vishwanath (1931) observed that use of mineral fertilizers gave better yield response than did farmyard manure during the first thirty six croppings but afterwards the organic manure was superior between the 37th and 56th crops in the Permanent Manurial Experiment at Coimbatore, India. Confirmatory evidence showing that balanced combinations of mineral fertilizers are equally effective and can sustain production over long periods has been given by Digar,1958; Patel *et al,*1963.

Raheja *et al,* (1965) concluded that application of nitrogen half as farmyard manure and half as ammcnium sulphate was better than in either form alone for wheat grown in alluvial loam (Table 24).

Table 24 Wheat yield with different amounts of FYM and ammonium sulphate alone and in combination during 1953-58 (Raheja *et al,*1965)

Treatment	Nitrogen kg/ha	Yield kg/ha	Average response
Control	-	1290	-
FYM	80	1510	210
FYM	120	1650	350
FYM (40 kgN/ha) + A.S.	40	1790	490
FYM (60 kgN/ha) + A.S.	60	1800	510

Naphade and Bhoyar (1974) while studying the effect of continuous application of farmyard manure with and without fertilizers upon the fertility of soil and yield of wheat observed that application of 6 157 kg/ha of manure together with NPK gave the maximum yield; the soil was a calcareous black clay (Table 25)

Table 25 Yield of wheat grain with different fertilizer treatments (Naphade and Bhoyar, 1974)

Amount of FYM kg/ha	$N_oP_oK_o$	N	P	K	NP	NK	PK	NPK
0	1098	1623	1330	1460	1686	1584	1473	1769
1235	1460	1804	1555	2041	1801	1891	1779	1941
6175	2067	2067	2001	2053	2342	2245	-	2455

N 25 kg/ha; P 5.5 kg/ha; K 20.7 kg/ha

Srivastava and Khanna (1974) reported the results of experiments carried out under the Coordinated Soil Test Crop Response Scheme of ICAR at Hissar in India (Table 26). Increased yield of crops after incorporation of manure together with fertilizer was attributed by these workers to a decrease in loss of nutrients.

Table 26 Residual effect of FYM alone and with mineral fertilizer on the yield of wheat (Srivastava and Khanna, 1974)

Treatment applied to the preceding crop (kg/ha)	Yield of succeeding wheat crop kg/ha
FYM (15 000)	1894
FYM (15 000) + 60 min.fert.N	1942
FYM (15 000) + 120 min.fert.N	2437

Results obtained from a long term trial at the same station on wheat yields with different combinations of manure and fertilizer nitrogen are given in Table 27. It was concluded that, from the economic view, manure should be applied at 15 000 kg/ha together with 120 kg/ha nitrogen.

Table 27 Effect of different combinations of farmyard manure and mineral nitrogen fertilizer on yield of wheat (Srivastava and Khanna,1974).

Treatments kg/ha	Wheat grain yield (4 year average) kg/ha
15 000 FYM + 60 N	2949
15 000 FYM + 120 N	3633
30 000 FYM + 60 N	2913
30 000 FYM + 120 N	3520
45 000 FYM + 60 N	3150
45 000 FYM + 120 N	3590

Formoli *et al* (1977) observed significant interaction of farmyard manure and phosphorus upon rice yield from sandy clay loam soils of Delhi, India. As a result it was recommended to apply phosphorus with manure to both the crops in a rice-wheat rotation.

Tandon and Verma (1978) found that for maintaining long term fertility of soils under rainfed conditions, the use of farmyard manure was essential. Best yields were obtained when mineral and organic fertilizers were used together (Table 28).

In another long term experiment, under irrigated conditions, application of organic manure was found to increase yields at all levels of mineral fertilizer application (Table 29).

Table 28 Effect of organic manure and mineral fertilizer upon yield of soybean and wheat in a sandy loam soil (Tandon and Verma 1978).

Treatments	Grain yield (kg/ha)	
	Kharif Soybean	Rabi Wheat
Control	1080	720
NP	1580	960
NK	1110	810
NPK	1770	1100
N- FYM	2360	1160
NPK-FYM	2640	1900

N added at 20 kg/ha; P at 35.2 kg/ha; K at 23.2 kg/ha

Table 29 Yield of wheat with various combinations of mineral fertilizer and organic manure (Tandon and Verma, 1978)

Mineral Fertilizer kg/ha	Farmyard Manure (kg/ha)		
	0	5 000	10 000
0:0:0	1370	1760	2120
40:13.2:16.6	2640	2830	3230
80:26.4:33.2	3260	3580	4060

Shukla and Chaudhary (1976) found that the efficiency of mineral fertilizers was increased if they were used in combination with organic manure (Table 30).

Table 30 Effect of nitrogen fertilizer alone and in combination with farmyard manure on the yield of wheat (Shukla and Choudhary,1976)

Treatment	Yield of wheat grain kg/ha	Available P kg/ha
Control	1370	3
Mineral N (60 kg/ha)	2664	2
Mineral N (120 kg/ha)	2914	1
Mineral N (120 kg/ha) + FYM at 15 000 kg/ha	3633	5

Farmyard manure was found to maintain the phosphorus fertility of the soil as well as increase crop yield. It was concluded that since the efficiency of organic nitrogen is only twenty five percent for the first crop with an additional twenty five percent for the next crop, a combination of organic manure with mineral nitrogen fertilizer would be necessary.

Dahiya *et al* (1980) observed that urea when used in combination with farmyard manure or rice husk resulted in higher wheat yield and nutrient uptake as compared to application of urea alone.

Experiments on the effects of application of compost and stable manure in Japan have shown that their application can increase the yield of upland crops by twenty five percent and of rice by ten percent (Shimizu, 1978). Some typical results are given in Table 31.

Table 31 Effect of manures upon yield of different crops in Japan (Shimizu, 1978)

Crop	Number of exp. sites	Average yield indices against NPK control	Quantities of manure kg/ha
Sugar beet	3	99	23 700
Maize	10	126	15 700
Beans and Pulses	8	123	16 800
Potatoes	18	118	15 500
Wheat and Barley	36	131	13 000
Other upland crops	15	115	13 000
Total: upland	90	125	15 500
Rice	56	110	11 000
Average	146	119	13 800

Sahu and Nayak (1971) carried out trials on a sandy loam lateritic soil of Bhubaneshwar in India. An analyis of the long term effect at the end of the tenth year showed that increase in yield due to organic manure was 684, 450 and 51 kg/ha of grain and 1451, 994 and 365 kg/ha of straw with farmyrad manure, green manure and oil cake respectively, when applied alone over the yields obtained during the first year. The corresponding increases in yields with applications of nitrogen at 22.5, 45.0, 67.5 and 90.0 kg/ha were 492, 434, 511 and 515 kg/ha grain and 53, 760, 1232 and 1081 kg/ha straw.

Interaction between ammonium sulphate and organic manure was not found significant for increasing grain yield but was significant in increasing yields of straw. The best combination for obtaining high yields of indica rice was 45 kg/ha N as mineral fertilizer with a basal dressing of farmyard manure to provide 45 kg/ha N (Table 32).

Table 32 Effect of organic manure with and without ammonium sulphate on rice yield.

Nitrogen added as ammonium sulphate kg/ha	Average yield (kg/ha) over 1956-1965			
	Without organic manure	With basal dressing of manure FYM 45 kg/ha N	Green leaf manure 45 kg/ha N	Groundnut cake 45 kg/ha N
0	2147	2443	2511	2402
22.5	2345	2468	2400	2364
45.0	2361	2667	2496	2390

In a long term manurial trial in Burma, the cumulative and residual effects of various manures and fertilizers on the yield of rice was investigated (Thant, 1978). The results are given in Table 33 and it can be seen that farmyard manure had a longer lasting effect than did the mineral fertilizers

Table 33 Cumulative and residual effects upon rice yield of various fertilizers and manures (Thant, 1978)

Treatment	1945-46	1949-50	1953-54
	Rice yield in kg/ha		
Control	1643	1692	1262
Lime at 5cwt CaO/acre once in 4 years	1586	1702	1267
Sodium nitrate, at 44 kg/ha N	1575	1650	1250
Ammonium sulphate at 44.8 kg/ha N	1690	1614	1236
Superphosphate at 20.2 kg/ha P	2223	1917	1597
Bonemeal at 44 kg/ha P	1702	1745	1331
Potassium sulphate at 37 kg/ha K	1555	1777	1279
Ammonium sulphate + superphosphate	2084	1976	1421
Amm.sulphate + super-phosphate + pot.sulphate	2007	2025	1612
FYM at 44.8 kg/ha N	2325	2240	1903

Experiment was a student design and had control and fertilizer treatments side by side with four replicates. The experiments started in 1925 and application of manure continued until 1942.

The synergistic effect of farmyard manure and mineral fertilizers on the yield of short ˉtaple cotton was investigated during 1969-1970 (Thant. 1978). The results are shown in Table 34 and it mav be seen that the combination of farmyard manure with chemical fertilizers has given better yields as compared to their separate use.

Table 34 Effect of organic manure and mineral fertilizer on yield of short staple cotton (Thant, 1978)

Treatment			Yield	Merit order
FYM kg/ha	N kg/ha	P kg/ha	kg/ha	
0	0	0	174	9
4480	0	0	280	5
8960	0	0	420	1
0	11.2	4.9	196	7
0	22.4	9.9	189	8
4480	11.2	4.9	288	4
4480	22.4	9.9	234	6
8960	11.2	4.9	332	3
8960	22.4	9.9	336	2

Experiments on long term repeated application of compost and stable manure to paddy fields in Japan show that the higher the quantity applied and the longer the periods of application are continued, the greater the effects of yield increase. Furthermore, it has been shown that the effect of organic manure are greatest in years having unfavourable weather conditions such as cold spells, during the cropping period (Shimuzu, 1978).

In Tables 35 to 38 are given experimental results of field trials in Japan upon the effects of mineral fertilizers and organic manures upon the yields of rice and again, it has been shown that the best effects come from complementary use of the materials.

Jugsijinda *et al* (1978) have summarised the results obtained in Thailand of experiments with mineral fertilizers and organic manures (Tables 39 and 40). It was found that organic matter did not benefit the heavy clay soil of the Central Plain (Bangkhen) in the short term but was effective in the north-eastern district of Surin. Farmyard manure is the most widely used and appreciated manure among Thai farmers and its use has been found to increase rice yields up to about twenty percent when applied at rates from 3 000 to 6 000 kg/ha.

Table 35 Effects of compost and stable manure on the yield of lowland rice in Japan (Shimuzu, 1978)

Year	No lime	NPK + lime	7 500 kg/ha manure	22 500 kg/ha manure
1925-30	3320	3490	3560	3800
1931-35	3150	3470	3680	3920
1936-40	3640	3620	4010	4610
1941-45	3140	3400	3720	4480
1946-50	3680	3890	4250	4710
1951-55	3440	3470	4050	4640
1961-65	3110	3540	4060	4590
Average	3400	3610	3960	4420
Average of typhoon years	3300	3550	3970	4540
Average of low yield years	2930	3060	3560	4040

Typhoon years: 1949,1950,1954,1956,1958,1959,1961,1965
Low yield (unfavourable weather) years: 1929,1931,1934,1937,1943,1944,1953 1958,1959

Table 36 Effects of mineral nitrogen, compost and cattle dung on rice yield in Techigi, Japan (Harada,1952)

Treatment kg/ha	Yield index (21 year average) of unhulled rice
Control	100
Compost at 11 115	103
Cattle dung at 11 115	112
Ammonium sulphate, 55.6 N	130
N + compost 55.6 N + 11 115	130
N + dung 55.6 N + 11 115	135

Table 37 Response of paddy to compost and mineral fertilizer in Japan (Harada, 1952)

Treatment	Rate	Yield index (unmilled rice)
Control	-	100
Compost	11 115 kg/ha	108
NPK	(not given)	140
Compost + NPK	11 115 + ?	149

Table 38 Response of paddy to compost and mineral nitrogen at different locations in Japan (Harada, 1952)

Treatment	Rate	Yield index for unmilled rice		
	kg/ha	Hokukaido[1]	Aomori[2]	Fukushima[3]
Control	-	100	100	100
Compost	11 115	111	123	106
Nitrogen	37	106	-	-
Nitrogen	55.6	-	136	184
Compost + N	11 115 + 37	116	-	-
Compost + N	11 115 + 55.6	-	150	208

1: one year experiment; 2: mean of 20 years; 3: mean of 5 years

Table 39 Effect of organic manure upon rice yield in combination with water management, at Bangkhen, Thailand (Jugsijinda *et al*, 1978)

Water management	Organic material	Nitrogen level (kg/ha) 0	37.5	75	112.2	Average kg/ha
Undrained	Control	3944	4556	5010	5186	4674
	City compost	4005	4515	5000	5094	4654
	Rice straw	4354	4635	5291	5930	5053
	Average	4101	4569	5100	5403	
Drained	Control	3368	3780	4471	4527	4283
	Compost	3639	4326	4819	4781	4391
	Straw	2653	3654	4384	4985	3919
	Average	3220	3920	4558	4764	

Table 40 Effect of organic matter upon rice yield in combination with water management, at Surin, Thailand (Jugsijinda *et al*,1978)

Water management	Organic material	Nitrogen level (kg/ha) 0	37.5	75	112.2	Average kg/ha
Undrained	Control	2010	2631	2865	2989	2624
	Compost	2621	3071	3699	3970	3340
	Rice straw	2676	3056	3388	3873	3248
	Average	2436	2919	3317	3611	
Drained	Control	2019	2704	3236	3522	2870
	Compost	2806	3543	4225	4326	3725
	Straw	2204	2961	3136	3886	3047
	Average	2343	3069	3532	3911	

The effects of city waste compost and farmyard manure upon rice yield were also studied by Jugsijinda *et al* 1978) and the results are given in Table 41. It can be seen that application of compost at rates of 1817, 3125 and 6250 kg/ha increases the rice yield in proportion to the amount applied with average yield increases of 11, 21 and 30 percent respectively. The data further suggest that application of city compost at 6250 kg/ha combined with 12.5 kg/ha N and 11 kg/ha P gives better yields of rice than almost any other soil treatment, including the comparatively high rates of mineral fertilizer alone.

The results from six rice experimental stations during 1961-64 are given in Table 42 and reveal that higher yields are obtainable through combined use of mineral fertilizer and compost.

Table 41 The effects of city waste compost, farmyard manure and mineral fertilizer upon rice yield in Thailand (Jugsijinda *et al*, 1978)

Treatment kg/ha	Locations and rice yield in kg/ha RST	KSR	PAN	SRN	PMI	NSR	BKN	GPA	Mean	Percent increase over control
Control	1639	2186	2526	1735	2030	1887	2670	2061	2095	-
Compost at 1875(a)	1612	2282	2501	2155	2209	2567	2904	2387	2327	11.1
Compost at 3125(b)	1899	2655	2741	2426	2403	2834	3128	2346	2554	21.9
Compost at 6250(c)	2161	2990	2822	2527	2771	2725	3291	2655	2743	30.9
FYM at 1875 (a)	1561	2644	2691	2174	2156	2447	2916	2370	2370	13.1
FYM at 3125 (b)	1334	2831	2670	2162	2493	2577	3113	2477	2457	17.3
FYM at 6250 (c)	1491	2722	2803	2542	2396	2510	3245	2683	2549	21.7
Compost + NPK* (a)	1754	2920	2869	2697	2482	2923	3167	2584	2674	27.6
Compost + NPK* (b)	1616	2977	2743	2583	2709	2786	3168	2727	2664	27.2
Compost + NPK* (c)	2325	3062	2938	2773	3141	2986	3256	3306	2973	41.9
FYM + NPK* (a)	1692	2766	2890	2406	2340	2800	3072	2615	2573	22.8
FYM + NPK* (b)	1553	2879	2837	2483	2803	2682	3301	2675	2652	26.6
FYM + NPK* (c)	1627	3100	2956	2705	3060	2844	3352	2871	2814	34.3
NPK at 37.5:11:0	1604	2859	3016	2821	3259	3029	3140	2822	2818	34.5

* 12.5:11.0:0

RST = Rangsit Rice Experimental Station, Pathoomthani
KSR = Koksamrong Rice Experimetal Station. Lopburi
PAN = Pan Rice Experimental Station, Chiengrai
SRN = Surin Rice Experimental Station, Surin
PMI = Pimai Rice Experimental Station, Nakornrajsrima
NSR = Nakornsrithamaraj Rice Experimental Station, Nakornsrithamaraj
CPA = Chumpae Rice Experimental Station, Khonkhaen
BKN = Bangkhen Rice Experimental Station, Bangkok

Table 42 Effects of mineral fertilizer and organic manures upon rice yield in Thailand (Williams, 1978)

Treatment	Application rate kg/ha	Yield of rough rice $kg/12m^2$
Control	-	2.347
City compost	1825	2.666
	3125	2.992
	6250	3.199
Farmyard manure	1825	2.734
	3125	2.813
	6250	2.893
Compost + NPK	1825 + 12.5:10:0	3.129
	3125 + 12.5:10:0	3.081
	6250 + 12.5:10:0	3.443
FYM + NPK	1825 + 12.5:10:0	2.979
	3125 + 12.5:10:0	3.048
	6250 + 12.5:10:0	3.258
NPK	12:5:10:0	3.317

Shinde and Ghosh (1971) observed significant interaction between farmyard manure and nitrogen and phosphorus on the yield of paddy in a medium black soil (Table 43)

Table 43 Interaction of farmyard manure and mineral fertilizer and its effects upon rice yield (Shinde and Ghosh,1971)

	N_o	N_1	N_2	P_o	P_1	P_2	K_o	K_1	K_2	Mean
No manure	950	1350	1550	810	1460	1580	1240	1310	1300	1280
FYM,5600 kg/ha	1400	1730	2070	1580	1690	1930	1701	1760	1740	1730
Mean	1180	1540	1810	1200	1580	1760	1480	1530	1520	-

N_1 - 33.6 kg/ha, N_2 - 67.2 kg/ha, P_1 - 14.8 kg/ha, P_2 - 29.6 kg/ha

K_1 - 27.9 kg/ha, K_2 - 55.8 kg/ha

Data from a long term experiment on combined application of organic manures and mineral fertilizer for four seasons (1976-78) at Hyderabad in India as reported by Pillai (1978) indicate the usefulness of farmyard manure application at least once in a season over a moderate level of mineral nitrogen for maintaining stability in rice yields. However, with crop residues as manure, the results were not consistent Table 44).

Table 44 Grain yield of rice (Variety RP 4-14) as influenced by the combined application of mineral fertilizer and organic manures (Pillai, 1978)

Treatment	Grain yield, kg/ha (4 year average)			
	Organic manures applied during season:			
	Rabi and Kharif	Kharif only	Rabi only	Mean
Control	2870	2889	2719	2826
N at 40 kg/ha	3848	3725	3766	3780
N at 80 kg/ha	4876	4869	4566	4770
FYM at 5000 kg/ha	2976	2969	3109	3017
FYM + 40 kg/ha N	3720	3964	4072	3919
FYM + 80 kg/ha N	5017	4924	4872	4944
Crop residues at 5000 kg/ha	3030	3101	3173	3101
Crop residues + 40 kg/ha N	4139	4067	3883	4030
Crop residues + 80 kg/ha N	4684	4733	4339	4586
Mean	3907	3915	3835	3886

Meelu and Singh (1978) conducted experiments to study the possibility of economising on the use of mineral nitrogen through the use of farmyard manure for rice production at Ludhiana in India. Their data are given in Table 45.

Table 45 Effect of farmyard manure in replacing mineral fertilizer nitrogen for rice production (Meelu and Singh,1978)

Treatment	Yield of paddy, kg/ha
Control	2790
FYM_{12} N_o P_o	3180
FYM_o N_{120} $P_{8.8}$	6190
FYM_{12} $P_{8.8}$	5910

FYM in ton/ha; N and P in kg/ha

The data show that there was 300 kg/ha more yield with application of farmyard manure and that 12 000 kg/ha of the manure could save about 30 kg/ha of mineral nitrogen.

Chatterjee *et al*(1979) found that organic manure applied at 10 000 kg/ha four to five weeks before transplanting gave as much yield of rice as 40 kg/ha of mineral nitrogen applied as urea at transplanting time. Meelu *et al* (1981) showed that in three years rice grain yield with 80 kg/ha of mineral nitrogen in combination with 12 000 kg/ha of farmyard manure was comparable to that fertilized with 120 kg/ha of nitrogen. It was concluded that for rice, application of 12 000 kg/ha of farmyard manure can save 40 kg/ha of nitrogen (Table 46).

Table 46 Effect of farmyard manure on nitrogen economy for rice

FYM kg/ha	Nitrogen kg/ha	Grain yield (kg/ha) 1977	1978	1979	Average
0	0	2960	3060	3430	3150
12 000	0	3380	3960	4230	3850
12 000	40	5080	5230	5080	5160
0	120	6700	7030	6130	6620

The residual effect of farmyard manure was studied by Meelu *et al* (1981) in a rice - wheat rotation. It was found that application of 12 000 kg/ha of the manure not only economises 40 kg/ha of nitrogen but gave a residual effect equivalent to 30 kg/ha nitrogen and 13.2 kg/ha of phosphorus.

Meelu and Singh (1978) reported the results of experiments made on farmers' fields in the Jullundur district of India and the data revealed that the efficiency of farmyard manure is considerably increased by simulataneous use of mineral fertilizers. It was found that 12 000 kg/ha of the manure was equivalent to 30-60 kg/ha of nitrogen and 13.2 kg/ha of phosphorus (Table 47).

Table 47 Effect of organic manure and mineral fertilizer on maize yield (Meelu and Singh, 1978)

Treatment	Average yield for 1974-79 kg/ha
Control	1640
N_{120}	2970
FYM_{12}	2280
FYM_{12} N_{60}	2780
FYM_{12} N_{90}	3000
N_{120} $P_{26.4}$ $K_{24.9}$	3250
F_{12} N_{60} $P_{13.2}$ $K_{24.9}$	2950

Number of experiments was 14. FYM in ton/ha, NPK in kg/ha

Meelu and Rekhi (1981) gave the results of a field trial conducted on a soil which had low contents of available N,P and organic carbon (Table 48). The results indicated that rice grain yield when fertilized with 80 kg/ha of nitrogen with the addition of 12 000 kg/ha of farmyard manure was comparable to that obtained by using 120 kg/ha of nitrogen alone. The manure also gave a residual effect equivalent to 30 kg/ha of nitrogen and 13.2 kg/ha of phosphorus as mineral fertilizer for a succeeding crop of wheat. It was concluded that the manure could subsitute for 70 kg/ha of N and 13 kg/ha of P; it was found more beneficial to apply the manure to the rice crop than to wheat in the crop rotation.

Table 48 Effect of farmyard manure on nitrogen economy for rice at Ludhiana, India (Meelu and Rekhi, 1981)

FYM kg/ha	Nitrogen kg/ha	Grain yield (kg/ha) 1977	1978	1979	Average
0	0	2960	3060	3430	3150
12 000	0	3380	3960	4230	3850
12 000	40	5080	5320	5080	5160
12 000	80	6390	7430	6410	6740
0	120	6700	7030	6130	6620

In Table 49 are given the results of trials made with wheat in Nepal (Karki and Baral, 1978). The increase in yield was sixty three percent over the control due to use of compost alone and as much as one hundred and sixty percent increase was obtained at Jumla with a combination of mineral fertilizer and manure. At Khumal a combination of equal amounts of organic manure and mineral fertilizer (in terms of nutrients) increased the yield by forty six percent whereas fifty one percent increase was obtained by applying double the amounts. It may be noticed that at Khumal the yield of wheat declined with the use of organic manure and this was attributed to use of undecomposed material

Table 49 Effect of different combinations of compost and NPK upon wheat yield in Nepal (Karki and Baral, 1978)

Treatment	Jumla Yield kg/ha	Jumla Increment over control	Khumal Yield kg/ha	Khumal Increment over control
Control	937	-	2433	-
100% local compost at 20 000 kg/ha	1475	57	2150	- 11
100% improved compost at 20 000 kg/ha	1550	62	2125	- 12
50% compost and 50% NPK	1750	86	3563	46
100% compost and 100% NPK	2437	160	4650	91

100% NPK = 100:26.4:33.2 kg/ha

The effect of mineral fertilizers with and without manure upon yield of maize was studied at Kakani in Nepal by Karki and Baral (1978) and their results are given in Table 50. The data show that application of manure alone would not be sufficient to meet the nitrogen needs of the crop but its use in addition to mineral fertilizer gave increased yields. Best results were found with a combination of compost at 20 000 kg/ha and NPK at 60:17.6: 24.9 kg/ha.

Table 50 Effect upon maize yield of mineral fertilizer and organic manure (Karki and Baral, 1978)

Fertilizer (kg/ha)			Compost (kg/ha)	Maize grain yield (kg/ha)
N	P	K		
0	0	0	0	755
0	0	0	10 000	743
0	0	0	20 000	703
60	17.6	24.9	0	1191
60	17.6	24.9	10 000	1215
60	17.6	24.9	20 000	1337
120	52.8	66.4	60 000	1213

Prasad *et al* (1971) observed that continuous application of ammonium sulphate every year for seven seasons in the acid red loam soil of Bihar (India) markedly decreased the yield of maize. Lime, in conjunction with farmyard manure and phosphorus and potassium, or lime with NPK significantly increased yields (Table 51)

Table 51 Effect of repeated application of fertilizer and manure on maize yield in an acid soil (Prasad *et al*, 1971)

Treatment	Maize yield (kg/ha)	
	1964-65	1965-66
Control	410	754
Ammonium sulphate at N_{44} every season	951	870
$N_{44} + P_{19.4}$ (supers)	2394	2329
$N_{44} + P_{19.4} + K_{36.5}$ (as KCl)	1361	2729
FYM at 44 kg/ha N	2230	2000
FYM + $P_{19.4}$	2663	2329
FYM + $P_{19.4} + K_{36.5}$	2083	1738
Lime + NPK	2165	3142
Lime + FYM + PK	2729	2795

The effects of manure and fertilizer upon potatoes was studied by Singh and Srivastava (1971) and their results are given in Table 52.

Table 52 Effects of poultry manure and farmyard manure and mineral fertilizer upon yield of potato (Singh and Srivastava, 1971)

Treatment	Yield (kg/ha)
Control	6356
Poultry manure at 80 kg/ha N	7014
FYM at 80 kg/ha N	6381
Poultry manure (40 N) + FYM (40 N)	7006
Poultry manure (40 N) + Fertilizer(40 N)	9480
FYM (40 N) + Fertilizer (40 N)	9075
Average	7791
PM at 120 kg/ha N	10739
FYM at 120 kg/ha N	8358
PM at 60 N + FYM at 60 N	8669
PM at 60 N + Fertilizer at 60 N	11645
FYM at 60 N + Fertilizer at60 N	10744
Average	10031
PM at 160 kg/ha N	11022
FYM at 160 kg/ha N	9939
PM at 80 N + FYM at 80 N	9972
PM at 80 N + Fertilizer at 80 N	14220
FYM at 80 N + Fertilizer at 80 N	13383
Average	11707

The maximum yield was obtained by applying 80 kg/ha of nitrogen as poultry manure together with 80 kg/ha of nitrogen as mineral fertilizer and this was followed by using 80 kg/ha of nitrogen as fertilizer and the same quantity as farmyard manure. Poultry manure, in general, showed better results than farmyard manure. It was concluded that use of organic manures together with fertilizers is important for vegetable crops which are mostly uprooted thus leaving little organic residue in the soil.

Grewal and Sharma (1978) also observed that farmyard manure increased the yield of potatoes when added in addition to mineral fertilizer. Sharma (1979) later studied the cumulative, direct and residual effects of farmyard manure on potato yield in a permanent field experiment having a two year rotation of potato-wheat-peas on a brown hill soil. In the direct effect, farmyard manure applied at 44 kg/ha P, was as effective as superphosphate but less effective than the combined application of 44 kg/ha P and 125 kg/ha K. The farmyard manure in the cumulative effect gave a higher yield even than the combined use of P and K as fertilizer. The residual effects of manure were substantial and higher in a low rainfall year; the residual effects of mineral P K fertilizers were not discernable. Past applications of manure were more effective in maintaining yield levels than the mineral P source Table 53).

Table 53 Cumulative, direct and residual effects of phosphorus and potassium fertilizers and farmyard manure on the dry matter yield of potato tubers (Sharma *et al*, 1979)

Treatment	Yield (quintals/ha)		
	1972	1974	Mean
	Cumulative Effect		
44 kg/ha P	42.8	51.9	47.3
44 kg/ha P + 125 kg/ha K	53.6	56.3	55.0
88 kg/ha P + 125 kg/ha K	48.9	62.0	55.5
FYM to supply 44 kg/ha P	49.4	68.6	59.0
	Direct Effect		
44 kg/ha P	42.5	45.1	43.8
44 kg/ha P + 125 kg/ha K	54.4	58.3	56.3
88 kg/ha P + 125 kg/ha K	56.6	51.3	54.0
FYM to supply 44 kg/ha P	41.2	68.6	54.9
	Residual Effect		
44 kg/ha P	37.6	42.9	40.3
44 kg/ha P + 125 kg/ha K	37.1	41.2	39.1
88 kg/ha P + 125 kg/ha K	39.9	45.7	42.8
FYM to supply 44 kg/ha P	45.9	46.9	46.4
Control	33.1	41.2	37.1

Grewal and Sharma (1981) observed that the nitrogen needs of potato in hill soils were not reduced by the past application of nitrogen fertilizer but were by past application of farmyard manure (Table 54).

Use of farmyard manure and green manures increased the organic carbon and nitrogen status of a soil and this in turn reduced nitrogen responses. Use of farmyard manure to provide 44 kg/ha phosphorus proved more effective than mineral fertilizers in raising the yield of potatoes and other crops in the rotation. Inclusion of legumes in the rotation also improved yields. It was concluded that farmyard manure has little direct effect on modifying the fertilzer needs of potato but it exerts influence on the residual effect. Application of nitrogen as fertilizer and phosphorus and potassium as manure was advocated to obtain high yields in the rotation.

Average crop yields in a legume cropping system as affected by continuous manurial treatments for the period 1930 to 1969 in the Pusa Permanent Trials in India have been given by Ghosh (1981). The results show that organic manures are beneficial and that under rainfed cropping yield variations due tobad weather conditions were less in manured treatments than in fertilizer treatments.

Table 54 Direct and residual effects of manurial treatments on the yield of crops in a long term (1971-1980) experiment at Jullundur in India.

Treatment	Yield in kg/ha					
	Potato (autumn)	Potato (spring)	Wheat (autumn)	Wheat (spring)	Maize	Rice
			Direct Effect			
Control	15500	13400	4800	2860	3470	4500
44 kg/ha P	19200	19400	5130	3520	3420	4780
44 kg/ha P + 83 kg/ha K	21700	20400	4980	3590	3540	4740
FYM to supply 44 kg/ha P	24600	22200	5080	3690	3620	4930
			Residual Effect			
Control	15500	13400	4800	2860	3470	4500
44 kg/ha P	17800	15900	4910	3260	3410	4790
44 kg/ha P + 83 kg/ha K	18700	16200	5000	3300	3400	4720
FYM to supply 44 kg/ha P	21800	18700	5070	3440	3510	4870

Mandal (1965) reported that combination of three parts of nitrogen from organic source with one part from mineral source gave the best results for Jute yield (Table 55).

Table 55 Effect of continuous application of nitrogen from mineral and organic sources, alone and in combination, on the yield of jute over a period of nine years (Mandal, 1965)

Treatment kg/ha	Yield of jute: Fibre kg/ha	Percent increase over control
Control	1120	-
Compost at 10 000	1755	56.7
Compost at 7 500 + Amm.sulphate equiv.to 2 500 kg compost	1980	76.8
Compost 5 000 + Amm.sulphate equivalent to 5000 compost	1868	66.8
Compost 2 500 + A.S (7500 compost)	2054	83.4
Compost 2 500 + A.S.(10000 comp)	1905	70.9
Compost at 20 000	2390	113.4
Compost, 15 000 + A.S.(5000 comp.)	2540	126.8
Compost,10 000 + A.S.(10000 comp.)	2502	123.4
Compost,5 000 + A.S.(15 000 comp)	2428	116.8
Compost,5 000 + A.S.(20 000 comp)	2278	103.4
Compost at 40 000	2951	163.5
Compost 30 000 + A.S.(10 000 comp)	3249	190.1
Compost 20 000 + A.S.(30 000 comp)	2652	136.8

Mahagan *et al* (1974) obtained higher yields of celery with combined use of farmyard manure and mineral nitrogen than if either was used alone. A maximum yield of 2120 kg/ha was obtained with application of 160 kg/ha of nitrogen as mineral fertilizer together with 50 000 kg/ha of manure.

Sen and Kavitkar (1955) examined the results from a permanent manurial trial at Pusa (Bihar, India) which was started in 1932. The system of cropping was a four year, eight course rotation with maize in kharif followed by four rabi crops in the sequence oats, peas, wheat and gram. Mineral fertilizers were added half before the kharif sowing and half before rabi sowing. The soil was gangetic alluvium, a light loam and calcareous. The crops were irrigated. Table 56 gives the average maize yield after different crops.

Table 56 Average maize yield after different crops as affected by manurial treatments. Yields are the average of 20 years (1932-1951). Sen and Kavitkar, 1955

Treatment	Yield in kg/ha				
kg/ha	Oats	Peas	Wheat	Gram	Av.for all crops
Control	215	266	363	336	295
Farmyard manure, (44.8 kg N)	536	523	671	863	648
Oil cake (44.8 kg N)	741	679	790	1096	827
Amm.sulphate (44.8 kg N)	369	520	534	627	512
Pot.sulphate (46.5 kg K)	257	310	379	395	335
Superphosphate (39.5 kg P)	273	334	394	493	374
KP	205	264	363	380	303
NPK	486	515	645	737	596
NP	508	514	637	786	611
NK	390	501	571	561	506
Average for all treatments	398	443	535	628	

Treatment with oil cake gave the highest yield of maize in all the rotations and this was followed by farmyard manure.

Sen and Kavitkar in 1958 gave the yield data for 1932-52 for the four rabi crops, i.e. oats, peas, wheat and gram, that preceded maize. Each of these crops was grown five times during the period. The average yields are shown in Table 57.

Better response to farmyard manure than to oil cake was obtained for all four crops. The response to NPK was also high and almost equal to that from the manure for the cereals (oats and wheat) but not for the legumes.

Table 57 Effects on oats, peas, wheat and gram of long term manurial treatments (Sen and Kavitkar, 1958)

Treatment	Average yield of five seasons kg/ha				
	Oats	Peas	Wheat	Gram	Average
Control	579	290	391	514	444
Farmyard manure	1185	644	690	806	831
Oil cake	991	508	583	658	685
Mineral nitrogen	751	280	561	418	502
Mineral potassium	672	331	408	437	462
Mineral phosphorus	719	505	424	705	590
PK	595	486	353	601	510
NK	826	276	568	421	523
NPK	1166	494	668	610	735

The results obtained at the Central Rice Research Station at Cuttack in India as reported by Agarwal (1965)are given in Table 58 and show the effects of long term (1949-1956) application of mineral nitrogen and compost upon rice production.

Table 58 Long term manurial trials at Cuttack on rice production

Treatment	Mean yield of paddy	Mean rate of change with years
Nitrogen (kg/ha)	kg/ha	
0	2360	+ 33.34
22.4	2706	+ 55.09
44.8	2864	+ 55.09
67.3	2750	+ 85.63
89.7	2405	+ 99.43
Compost		
0	2591	+ 49.50
9 300	2644	+ 87.44

Nitrogen application in excess of 44.8 kg/ha did not increase yield. Compost alone and in combination with ammonium sulphate at 22.4 kg/ha N gave good response. The continuous application of nitrogen either as mineral fertilizer or in organic form did not result in decline of yield.

In another experiment at the same Station, significant response was obtained to the application of nitrogen at all levels (0, 22.4,44.8 kg/ha)

Significant response to application of compost was also obtained but nitrogen in the form of farmyard manure or compost was found to be only half or two thirds as effective as that in ammonium sulphate (Table 59).

Table 59 Yield of paddy as affected by long term fertilization

Years 1952-56	Nitrogen added as ammonium sulphate kg/ha			Compost added kg/ha	
	0	22.4	44.8	0	9 300
Paddy yield in kg/ha	2452	2945	3114	2641	3033

At the Sugarcane Research Station in Maharashra (India) a long term experiment was started in 1939. The findings (Table 60) show that a high response has been obtained to the use of fertilizers in combination with manure (groundnut cake and compost).

Table 60 Yield of sugarcane as affected by long term fertilization (Agarwal, 1965)

Treatment	Yield of sugarcane in kg/ha
No compost	
Control	31 062
Groundnut cake	103 509
Ammonium sulphate	61 845
Cake + A.S. 1:1	96 441
2:1	97 650
1:2	82 026
With compost	
Control	39 525
Groundnut cake	112 251
Ammonium sulphate	86 862
Cake + A.S. 1:1	107 880
2:1	112 995
1:2	103 137

Raheja *et al* (1971) reviewed the long term fertilizer experiments in crop rotations in India. The beneficial effect of continuous application of farmyard manure was noticeable at Nasirpur and Sriganganagar, where a two year rotation, maize-wheat-cotton, was used. It was also noted at Pantnagar

where a one year maize-wheat rotation was studied and at Reura Farm and at Powarkheda where a single crop of wheat was grown continuously (Table 61).

Table 61 Cumulative response to farmyard manure (Raheja *et al*, 1971)

Soil Type	Location	Year	Crop	Av.yield without manure	Response to 5 600 kg/ha FYM
Two Year Rotations					
Desert	Sriganganagar	1962-66	Maize	441	48
Deep,black	Gangavati	1957-66	Cotton	681	167
One Year Rotation					
Red/black	Reura Farm	1957-64	Wheat	801	523
Tarai	Pantnagar	1964-66	Wheat	1669	279

At Pantnagar, Reura Farm and Powarkheda the response to 5600 kg/ha of farmyard manure varied from 280 to 520 kg/ha of wheat grain. At Nasirpur and Sriganganagar the response varied between 90 and 140 kg/ha for wheat and from 75 to 270 kg/ha for cotton. When the manure application was raised to 11 200 kg/ha at Nasirpur, the response was of the order of 200 kg/ha for wheat and cotton. It was concluded that those soils having low organic carbon gave the best response to manures.

Application of farmyard manure showed a significant soil productivity build-up effect at Nasirpur in the case of cotton, at Sriganganagar and Pantnagar in the case of wheat and at Gangavati for Jowar.

Interaction of farmyard manure with mineral nitrogen was significant at Akola and Gangavati for jowar and at Nasirpur and Bhavanisagar for cotton. For three of these locations the response to manure was increased by mineral nitrogen but at Nasirpur the response to 33.6 kg/ha nitrogen remained unaffected by manure and declined at 67.2 kg/ha. At some places farmyard manure decreased responses of cotton and wheat to mineral phosphorus and of cotton and maize to responses to potassium.

At the locations in hot, peninsular India where soil moisture is very critical for crop production, the positive interaction between manure and mineral nitrogen was probably due to improved soil physical properties and conservation of moisture.

Residual effects were studied only at Nasirpur and the data for farmyard manure and mineral nitrogen are presented in Table 62.

Fairly positive results of residual response were observed between nitrogen and manure for all crops but phosphorus (data not given) showed a residual effect only for wheat.

Shinde and Ghosh (1971) reported the effect of continuous cropping and manuring upon crop yields in a medium black soil. The average data for rice over a period of ten years are given in Table 63.

Table 62:- Direct, residual and cumulative responses to manures and fertilizers with a two year crop rotation (1956-7 to 1966-7)

Crop	Response to farmyard manure in kg/ha		
	Av.yield without FYM	With FYM at 5600 kg/ha	FYM at 11200 kg/ha
<u>Direct response</u>			
Maize	1213	109	230
Wheat	1860	107	217
Cotton	1052	35	105
<u>Residual response</u>			
Maize	978	88	161
Wheat	1678	17	60
Cotton	923	33	94
<u>Cumulative response</u>			
Maize	1217	149	345
Wheat	2098	89	212
Cotton	908	75	201

Table 63: Mean yield of paddy in a fixed crop rotation, 1956-66

Grain yield in kg/ha											
FYM x Phosphorus				FYM x Nitrogen				FYM x Potassium			
	F_o	F_1	Mean		F_o	F_1	Mean		F_o	F_1	Mean
P_o	811	1577	1194	N_o	950	1398	1174	K_o	1235	1707	1470
P_1	1563	1688	1575	N_1	1349	1725	1537	K_1	1312	1745	1529
P_2	1675	1929	1752	N_2	1550	2071	1810	K_2	1302	1743	1522
Av.	1283	1731		Av.	1283	1731		Av.	1283	1731	

F_o - No manure
F_1 - 5 600 kg/ha

P_o - No phosphorus
P_1 - 14.8 kg/ha P
P_2 - 29.6 kg/ha P

N_o - No nitrogen
N_1 - 33.6 kg/ha N
N_2 - 67.2 kg/ha N

K_o - No potassium
K_1 - 27.9 kg/ha K
K_2 - 55.8 kg/ha K

Number of plots averaged were 27 each for F_o and F_1 and 18 each for other treatments.

The highly significant effect observed with farmyard manure in improving soil productivity with continuous application agrees with the findings of Basu and Kibe (1945), Sannyasi Raju (1952) and Ghosh and Kanzaria (1964). A significant interaction of farmyard manure with nitrogen and phosphorus was observed.

Maurya and Ghosh (1972) investigated the effect of long term manurial and rotational cropping practices on the fertility status of alluvial calcareous soil in India. The average crop yields for the last forty years indicate the value of farmyard manure under rainfed farming. A comparable efficiency was observed with mineral NPK fertilizer. The results are given in Tables 64 and 65.

Table 64 Average crop yields in the old permanent manurial experiment at Pusa, India for the period 1930 to 1969

Treatment	Grain yield in kg/ha				
	Maize	Wheat	Barley	Arhar	Pea
	37 crops	9 crops	10 crops	8 crops	10 crops
Control	343	253	326	551	128
FYM at 8960 kg/ha	1410	911	1013	1211	584
FYM at 4480 kg/ha	1152	669	680	1049	345
Rape cake (44.8 kg/ha N)	1117	513	681	884	226
FYM at 4480 + Rape cake (22.4 kg/ha N)	1368	761	959	1074	471
Amm.sulphate (44.8 N)	415	275	359	710	130
Superphosphate (39.4 P)	685	560	708	1101	341
Pot.sulphate (46.5 K)	485	319	383	734	157
NP	678	671	942	1230	369
PK	753	603	630	1092	355
NK	340	273	423	523	101
NPK	906	757	1006	1111	383
Green manure in cereal rotation	-	531	489	-	-
Green manure in legume rotation	545	513	745	654	220
Green manure + P	799	1191	1634	1067	529
No green manure and no legume	296	216	205	-	-

Under rainfed cropping climatic vagaries bring down the efficiency of mineral fertilizers to a greater extent than of the organic manures. It is evident that in years of unfavourable rainfall the relative effect of farmyard manure was best.

Table 65 Average crop yields in the New Permanent Manurial Experiment at Pusa in India for the period 1932 to 1969

Treatment	Yield in kg/ha (mean of 10 replicates)				
	Maize 35 crops	Wheat 9 crops	Oats 8 crops	Pea 9 crops	Gram 9 crops
Control	474	375	469	380	344
FYM at 8960 kg/ha	1009	709	793	825	1045
Rape cake (44.8 kg/ha N)	1095	567	695	626	811
Amm.sulphate (44.8 N)	705	530	611	386	600
Superphosphate (39.4 P)	571	436	529	539	544
Pot.sulphate (46.5 K)	489	403	462	442	577
NP	799	628	748	562	773
PK	454	381	462	505	739
NK	688	555	617	373	608
NPK	780	626	728	557	760

An outstanding benefit from green manuring together with application of superphosphate for sunhemp has been observed and the mean yields of cereals (wheat and barley) have been 1.8 to 2 times that found with treatment with farmyard manure and more than three times that obtained by green manuring. This indicates that green manuring itself, whether in legume or cereal rotation, is not very effective and the high response found to green manuring plus phosphorus is mostly due to the phosphorus. Swarup and Ghosh (1979) gave the results of a long term field experiment at New Delhi involving multiple cropping with high yield pearl millet-wheat-cow pea fodder on a slightly alkaline alluvial sandy loam. Application of nitrogen and phosphorus significantly increased the yields of all crops; there was no response to potassium, zinc or farmyard manure (Table 66).

Table 66 Grain yield of crops as affected by fertilizer and manure treatment

Treatment	Yield in kg/ha				
	Pearl Millet		Cowpea fodder	Wheat	
	1973	1974	1974	1973-4	1974-5
Control	1080	1210	690	2820	1950
50% optimum NPK	1610	1910	860	3550	330
100% optimum NPK	2250	2810	1160	3910	4060
150% optimum NPK	2630	3170	1470	4620	4530
100% opt NPK + weeding	2390	2820	1230	3730	3930
100% opt NPK + Zn	2390	2820	1230	3700	4110
100% opt NP	2010	2620	1070	3370	3800
100% opt N	1570	1830	940	3130	3030
100% opt NPK + FYM	2490	2830	1200	4210	4480
100% opt NPK + S	2310	2690	1580	3750	4280

Sekhon (1974) summarised crop responses to farmyard manure in cropping sequences. Responses were large for wheat and maize rotation but were generally small for rice and bajra. Table 67 gives the direct, residual and cumulative responses of four crops to farmyard manure.

Table 67 - Direct, residual and cumulative responses of four crops to farmyard manure applied at 15 000 kg/ha in four cropping sequences (Sekhon, 1974)

Crop	Cropping sequence	Location	Grain yield in kg/ha		
			Direct	Residual	Cumulative
Rice	rice-rice	Bhubaneshwar	59	31	- 7
	rice-wheat	Varanasi	52	63	153
	rice-wheat	Bichpuri	236	152	265
	rice-wheat	Kathulia	309	185	247
Maize	maize-wheat	Ludhiana	1358	740	1545
Bajra	bajra-wheat	Hissar	288	197	225
Rice	rice-rice	Bhubaneshwar	32	177	61
Wheat	rice-wheat	Varanasi	303	331	352
	rice-wheat	Bichpuri	460	406	633
	rice-wheat	Kathulia	251	157	569
	maize-wheat	Ludhiana	1195	1195	1117
	bajra-wheat	Hissar	340	298	372

Sekhon (1978) also reviewed the results obtained from experiments made on farmers' fields in the Punjab (India) during the years 1974 to 1976 to find the extent to which farmyard manure can subsitute for fertilizers. NPK was added with or without the manure and the manure was applied at rates of 6 000 and 12 000 kg/ha. The results are given in Table 68.

Table 68 Effect of NPK application with and without farmyard manure on the yields of maize and wheat in the Punjab (Sekhon,1978)

Treatments (kg/ha)					Grain yield in kg/ha (average of 14 experiments for maize 12 for wheat)	
N	P	K	$ZnSO_4$	FYM	Maize	Wheat
120	26.4	49.8	50	0	3430	3660
60	13.2	24.9	50	0	2740	2830
105	23.1	43.6	0	6 000	3290	3590
90	19.8	37.3	0	6 000	3270	3310
60	13.2	24.9	0	6 000	2990	2960
45	9.9	18.7	0	6 000	2930	2720
90	19.8	37.3	0	12 000	3370	3440
60	13.2	24.9	0	12 000	3200	3070
30	6.0	12.5	0	12 000	2800	2510

The results show that farmyard manure substituted fertilizers to the extent of half the nutrient content when it was applied to maize and about one quarter when applied to wheat.

Meelu and Rana (1978) found that the efficiency of organic manure differs with crops. Kharif crops in general are more responsive to farmyard manure than Rabi crops (Table 69).

Table 69 Effect of farmyard manure upon crop response

Treatment	Yield response in kg/ha (average of 5 years)
15 000 kg/ha FYM on maize	2670
15 000 kg/ha FYM on wheat	1770

Ghosh (1980) summarised the results obtained from a long term fertilizer experiment made at different locations in India over the period 1971 to 1979 (Tables 70 to 73).

Annual supplements with farmyard manure at 10 000 to 15 000 kg/ha over 100% optimum NPK treatments led to a general improvement in crop production in several places. Manure dressings also resulted in increased nutrient uptake. Application of the 100% optimum NPK (based on soil testing) in an intensive cropping system also contributed towards improvement of the soil fertility. The additive effect of the manure was quite evident. Increasing the mineral fertilizer to 150% of the optimum was found to further raise soil fertility in a way comparable to that found by adding organic manure. A study of bacterial counts showed that certain treatments (100% NPK with sulphur and NPK with FYM) maintained a high bacterial population.

Mahapatra *et al* (1981) have reported the results obtained through long term manurial trials at a number of places in India for collecting information on the direct, residual and cumulative effects of phosphorus, potassium fertilizers and farmyard manure in a fixed single year, two crop rotation (Table 74). The twelve combinations of two rates of farmyard manure (0 and 15 000 kg/ha), three rates of phosphorus (0, 13.2, 26.4) and two rates of potassium (0, 24.9) were made in the main plots whereas the three phases of manuring, namely application during kharif only, during rabi only and during both seasons, were in sub-plots. A basal dressing of 100-120 kg/ha of nitrogen was given to both crops in the rotation.

The response to the application of 26.4 kg/ha of phosphorus in the kharif season only ranged around 600 to 800 kg/ha at all places whereas the corresponding response at Maruteru to 13.2 kg/ha P was 320 kg/ha. At Tirupati a high response of 1100 kg/ha was found to 26.4 kg/ha P given in the rabi season only. The application of 24.9 kg/ha K in the kharif season only gave a response of 300 kg/ha for all places. A cumulative response of the order of 340 kg/ha was observed at Bhubaneshwar to an application of 24.9 kg/ha K when applied every season. The response to farmyard manure was almost negligible at Thanjavur and Maruteru. A cumulative response to manure of a very high order (about 2300 kg/ha) was found at Mangalore where FYM was given

Table 70 Average yield of wheat under various treatments during the period 1971-1979 at different locations in India (Ghosh, 1980)

Treatment	Grain yield in kg/ha					
	New Delhi (8 crops)	Ludhiana (8 crops)	Pantnagar (7 crops)	Jabalpur (7 crops)	Barrackpore (9 crops)	Palampur (7 crops)
Control	2100	700	1720	1200	900	310
100% opt.N	3400	2580	4050	1680	2390	700
100% opt.NP	3930	3490	3910	3700	2390	3180
50% opt.NPK	3380	2690	2840	3040	1930	2390
100% opt NPK	4110	4110	3890	3840	2560	3540
150% opt.NPK	4560	4160	4580	4140	3000	3960
NPK + Zn	4150	4160	3930	4000	2420	3690
NPK + S	4360	4100	3900	3790	2570	4280
NPK + weeding	4100	4230	4310	3840	2570	3590
NPK + FYM	4400	4130	4220	4370	2540	4430

100% optimum NPK was, in New Delhi - 120:26.4:33.2 kg/ha
Ludhiana - 150:33.0:31.1 kg/ha
Pantnagar - 120:26.4:33.2 kg/ha
Jabalpur - 120:35.2:49.8 kg/ha
Barrackpur- 90:39.6:37.3 kg/ha

Table 71 Average yield of rice (unhusked grain) under various treatments during the period 1971-1979 at different locations in India (Ghosh, 1980)

Treatment	Yield in kg/ha				
	Barrackpore (9 crops)	Bhubaneshwar Rabi, 8 crops)	Bhubaneshwar (Kharif,7 crops)	Pantnagar (8 crops)	Hyderabad (14 crops)
Control	1940	1600	1770	4640	1990
100% opt.N	4120	2950	2610	6330	3720
100% opt.NP	4460	3080	2550	6140	4040
50% opt.NPK	3490	2570	2430	6060	3180
100% opt.NPK	4660	3380	2760	6920	4200
150% opt.NPK	4700	3480	3030	6790	5220
NPK + Zn	3870	3540	2770	6850	4210
NPK + S	3300	3310	2590	6440	4120
NPK + weeding	4530	3270	2840	6800	4170
NPK + FYM	4530	3760	2850	7780	4690

100% optimum NPK was, in Barrackpore - 120:26.4:49.8 kg/ha
in Bhubaneshwar- 100:26.4:49.8
in Pantnagar - 120:26.4:37.3
in Hyderabad - 125: 8:8:29.9

Table 72 Average yield of maize under various treatments during the period 1971-1979 at different locations in India (Ghosh, 1980)

Treatment	Grain yield in kg/ha		
	Ludhiana (7 crops)	Palampur (6 crops)	Coimbatore (5 crops)
Control	490	380	270
100% N	1340	2110	400
100% NP	2010	3270	1860
50% NPK	1690	2030	1430
100% npk	2770	3450	1800
150% NPK	2790	4480	2070
NPK + Zn	2790	3680	2000
NPK + S	2740	4080	1960
NPK + weeding	3100	3340	1850
NPK + FYM	3240	4630	2320

100% optimum NPK was, in Ludhiana - 150:33.0:62.2 kg/ha
in Palampur - 120:26.4:49.8
in Coimbatore- 135:29.9:29.0

Table 73 Average yields of jute fibre, cowpea, soybean, potato and rabi during the period 1971-1979 at different locations in India (Ghosh, 1980)

Treatment	Jute	Cowpea		Soybean		Potato	Ragi	
	Barrackpore (8crops)	Bangalore (7 crops)	Coimbatore (5 crops)	Jabalpur (5 crops)	Ranchi (6 crops)	Ranchi (6)	Bangalore (5 crops)	Coimbatore (5 crops)
Control	1410	-	-	980	1060	4240	-	-
100% opt.N	2190	150	330	1240	760	2390	200	990
100% opt.NP	2210	800	560	1700	1220	5270	1400	2630
50% opt.NPK	1930	870	560	1670	1080	5890	1160	1980
100% opt.NPK	2330	1090	570	1870	1390	7080	1540	2380
150% opt.NPK	2510	1230	620	1990	1340	7030	1780	2650
NPK + Zn	2340	-	590	1910	-	-	-	2490
NPK + S	1930	1080	650	1820	-	-	-	-
NPK + Lime	-	1060	-	-	1780	7400	1460	2490
NPK + weeding	2360	1250	580	1900	1310	7250	1600	2700
NPK + FYM	2320	1120	670	2080	1630	8150	1320	3050

100% optimum NPK was, in Barrackpore - 60:13.2:49.8 kg/ha
in Bangalore - 25:22.0:20.7
in Coimbatore - 90:10.8:14.5
in Jabalpur - 20:35.2:16.6
in Ranchi - 25:26.4:33.2

Table 74 Fertilizer requirement of single year rice-rice cropping system (Mahapatra, 1981)

Location	Average results for	Phosphorus			Potassium			Farmyard Manure		
		Season/ dose in kg/ha	Av.yield in plots without P	Response kg/ha	Season/ dose in kg/ha	Av.yield in plots without K	Response kg/ha	Season dose in kg/ha	Av.yield in plots without FYM	Response kg/ha
Sub-humid to humid; eastern and southeastern uplands										
Maruteru	1971-77	Kharif 13.2	8299	320	Rabi 24.9	8578	105	Kharif 15000	8446	136
Tirupathi	1972-76	Rabi 26.4	9923	1113	Rabi 24.9	10322	341	Every season	10280	650
Chiplima	1975-79	Kharif or Rabi 26.4	5388 5422	822 815	Kharif 24.9	5690	323	Kharif 15000	5567	570
Bhubaneshwar	1970-79	Kharif or Rabi 26.4	6419 6463	602 596	Every season 24.9	6791	343	Kharif 15000	6456	477
Humid to semi-arid western Ghats										
Karaiyiruppu	1971-76	Kharif 26.4	8352	313	Kharif 24.9	8441	203	Kharif or Rabi 15000	8385 8393	317 355
Karman	1972-78	Rabi 13.2	8197	poor	Kharif 24.9	8212	Poor	Every season 15000	7886	810
Mangalore	1972-79	Kharif 26.4	8550	poor	Kharif 24.9	8427	322	Every season	7738	2311
Thanjavur	1971-79	Kharif 26	7381	796	Kharif or Rabi 24.9	7673 7646	285 309	Kharif or Rabi 15000	7745 7731	142 140

in every season. A response of 650 and 810 kg/ha was observed for Tirupati and Karamana when farmyard manure is applied only during the kharif season and the corresponding responses for Chiplima and Bhubaneshwar were 570 and 480 kg/ha.

Mahapatra *et al* (1981) also reported the total produce, net profit and cost benefit ratio of a rice-rice cropping system with and without manuring as influenced by inorganic fertiizers at different levels of nitrogen (Tables 75 and 76). It was observed that the total produce with application of N_{90} plus farmyard manure for kharif rice and with N_{60} for rabi rice was very close to N_{120} P_{60} for kharif rice for the Puri and Tirunelvelli districts while the equivalence of total produce with farmyard manure with high level of nitrogen was restricted to only N_{120} for Mysore district; the total produce for this district was corresponding to N_{120} P_{60} or to N_{120} P_{60} K_{60}, for kharif rice and N_{60} for rabi rice. The cost benefit ratios were high where manure was applied during the kharif season, the highest being in Tirunelvelli, the order being around 5.

4.2 Use of fertilizers and organic manures in dryland farming

Mann and Singh (1978) report that in a long term experiment made at the Central Arid Zone Research Institute, application of farmyard manure at 40 000 kg/ha once in two years resulted in higher yield of bajra than the application of 40 kg/ha of mineral nitrogen every year. A thirteen percent depletion in organic matter content of the topsoil was observed due to the continuous cropping of bajra without any fertilization or manuring. Plots fertilized with mineral nitrogen and lower amounts of manure maintained their organic matter content and where manure was applied at 40 000 kg/ha once in two years, a twenty four percent build up was found (CAZRI, 1977).

Venkateswarlu and Spratt (1977) suggested that combination of organic manure and mineral fertilizer may prove to be the best treatment for increasing fertilizer use efficiency and crop yields in dryland conditions. The effect of organic residues in low level fertilizer management is given in Table 77.

Table 75 Total produce, net profits and cost benefit ratios of a rice-rice system for different levels of nitrogen with basal dressing of farmyard manure at 12 000 kg/ha applied during the kharif season (Mahapatra, 1981)

Location	Period	Total Produce kg/ha			Mean net profit*			Cost benefit	
		N_0	N_{60}	N_{90}	N_0	N_{60}	N_{90}	N_{60}	N_{90}
Sub-humid to humid uplands									
Puri	1975-77	6969	7635	7947	1628	2024	2201	2.81	2.57
Humid to semi arid									
Mysore	1975-77	9125	9880	10509	1791	2276	2770	3.16	3.24
Tirunel-velli	1974-78	11608	11875	11928	3723	3720	3638	5.16	4.25

* In rupees/ha

Table 76 Total produce, net profit (Rp/ha) and cost benefit ratios of a rice-rice system without farmyard manure (Mahapatra, 1981)

Location	Period	Total Produce kg/ha				Mean net profit				Cost benefit		
		N_0	N_{120}	$N_{120}P_{60}$	$N_{120}P_{60}K_{60}$	N_0	N_{120}	$N_{120}P_{60}$	$N_{120}P_{60}K_{60}$	N_{120}	$N_{120}P_{60}$	$N_{120}P_{60}K_{60}$
Sub-humid to humid uplands												
Puri	1975-76	6032	7421	8033	8273	871	1720	2002	2122	2.12	1.75	1.68
Humid to semi arid												
Mysore	1975-77	7762	10832	11404	12450	608	3138	3380	4306	3.87	2.96	3.41
Tirunel-velli	1974-78	10223	11454	12296	12593	2518	3209	3694	3898	3.96	3.24	3.09

Costs taken as: N = Rp.4.50/kg; P = Rp.12.50 /kg; K = Rp.2.41/kg; Rice = Rp.1.00/kg, FYM= Rp.15/1000 kg

Table 77 Role of organic manures in low level fertilizer management (Venkateswarlu and Spratt, 1977)

Treatment	Crop yield (kg/ha)
Control	642
Cattle manure	642
Compost	744
Crop residue	864
NPK at 20:20:0	1076
Manure + NPK	1122
Compost + NPK	910
Crop residue + NPK	1578

4.3 Effect of organo-mineral fertilizer combinations on crop yield

Pillai and Vamadevan (1978) carried out experiments with organo-inorganic combinations of fertilizers such as granulated compost and farmyard manure enriched with urea. The granulated compost was an organo-chemical fertilizer having an NPK analysis of 5:15:4 and consisted of 44% compost, 25% diammonium phosphate, 22% single superphosphate, 1% urea and 8% potassium chloride. Farmyard manure enriched with urea was prepared by treating dry manure or chopped crop residues with acid solutions of urea to supply a final product containing 5% nitrogen. The results are given in Table 78.

Table 78 Grain yield of rice (var.Rasi) as affected by mineral and organo-mineral fertilizers. (Pillai and Vamadevan,1978)

Treatment	Grain yield kg/ha Dry season	Wet season	Mean	Mean response to N (kg grain/kg N)
Control (no N)	3601	2527	3064	-
80 kg/ha N as urea,basal	5245	3858	4552	19
80 kg/ha N as urea, 3 splits	612	4032	4822	22
80 kg/ha N as S-coated urea, basal	5629	4398	5013	24
80 kg/ha N,organo-mineral	5647	3858	4752	21
80 kg/ha N, as FYM enriched urea, basal	5437	4186	4811	22
80 kg/ha N as gran.compost	5892	4398	5145	26
120 kg/ha N as urea,3 split	6364	4552	5458	20

Organo-mineral combinations of nitrogen were found to give better crop yields during both seasons. Single application of the same amount of nitrogen as granulated compost, farmyard manure-enriched urea or sulphur coated urea gave higher grain yields and were better than the best split treatment with urea.

Deb (1976) gave the results of a long term field experiment made with organo-mineral combinations of fertilizer (Table 79). It was found that organo-mineral mixtures were superior to farmyard manure alone and were comparable to mineral nitrogen and phosphorus effects. The organic matter content of soils showed a slight increase due to use of manure and organo-mineral materials.

Table 79 Effect of organo-mineral mixtures, mineral fertilizers and farmyard manure on grain yield during 1969-72 (Deb, 1976)

Treatment	Maize	Wheat	Maize	Wheat	Maize	Wheat
Control	1780	2080	2000	1700	1350	2100
Urea + superphosphate	3260	4480	4450	4650	4550	4500
Urea + superphosphate + dung	3580	3830	4300	4900	4400	4880
Urea + superphosphate + leaves	3530	4080	4180	4630	4930	4780
Enriched dung	3300	3880	4550	4730	5060	4300
Enriched leaves	3380	4250	3980	4750	4930	4300
Farmyard manure	2380	2730	2550	2890	3400	3450

Shinde *et al* (1975) tested the efficacy of the intimate blending of ground rice straw, urea and soil in the shape of a ball, as a slow release nitrogen source for rice. The results revealed that the performance of straw plus urea in terms of rice yield and nitrogen uptake was comparable to conventional slow release nitrogen sources (Table 80).

Table 80 Effect on rice yield of various compound fertilizers (Shinde,1975)

Treatment	Rice yield kg/ha	
	Saturated conditions	Flooded conditions
Control (no nitrogen)	1051	1819
80 kg/ha N as lac coated urea , basal application	2051	2861
80 kg/ha N as S-coated urea, basal application	2096	2570
Rice straw + Urea (80kg/haN)	1928	2583
80 kg/ha N as urea, split	1863	2348

4.4 Nitrification inhibiting organo-mineral fertilizers

As nitrogenous fertilizers are soluble, considerable quantities can be lost, especially under flooded conditions. To minimise such losses blending with nitrification inhibitors has been recommended. Blending with neem cake (*Azadirachta indica*, Jun.) has given good results. Ketkar (1976) reported the results from 325 trials conducted on farmers' fields (Table 81). He also reported that application of 22 kg/ha of neem cake together with 75 kg/ha mineral nitrogen gave a yield equal to that obtained with 100 kg/ha of mineral nitrogen alone at the Karjat Rice Research Station (Maharashtra, India).

Table 81 Effect of neem cake with mineral nitrogen on the yield of maize (Ketkar, 1976).

Treatment	Location in India				
	Khan Das	Damodar Das	Sarvet Ram	Atma Ram	Mean
Control	6420	4300	4530	4450	4430
60 kg/ha min.N	5140	5250	5690	5590	5420
60 kg/ha min.N + 26 kg/ha neem cake	6750	6250	6850	7030	6720
120 kg/ha min.N	6490	6490	7040	7250	6810
120 kg/ha min.N + 52 kg/ha neem cake	7510	7260	7790	8080	7660

The beneficial effects of blending neem cake with urea have also been reported by Reddy and Prasad (1977) and by Shanker *et al*(1975) and by Sinha *et al* (1975).

Table 82 Average yield of grain in transplanted and broadcast rice as affected by urea and neem cake (Shanker *et al*, 1975)

Treatment	Transplanted rice		Broadcast rice	
	Yield kg/ha	Increase over control %	Yield kg/ha	Increase over control %
Control	3796	-	3379	-
Neem cake at 20 kg/ha	4027	6	3509	3.8
60 kg/ha N as urea	4145	9.1	4028	19.2
60 kg/ha N as urea + 20% cake	4236	11.5	4213	24.6
90 kg/ha N as urea	4629	24.5	4768	44.0
90 kg/ha N as urea + 20% cake	5092	34.1	4954	46.6
120 kg/ha N as urea	5254	41.0	5000	47.9
120 kg/ha N as urea + 20% cake	5671	52.0	5602	65.7

Reddy and Prasad (1977) showed that urea mixed with neem cake gave yield increases similar to those given by lac coated urea (Table 83).

Table 83 Relative efficacy of different nitrogen sources for a rice wheat rotation (Reddy and Prasad 1977)

N source	Grain yield kg/ha					
	Rice		Wheat		Total	
	1972-3	1973-4	1972-3	1973-4	1972-3	1973-4
Urea	3290	3620	2370	2540	5660	6260
S-coated urea	3770	5040	3050	3240	6820	8280
Lac coated urea	3570	4160	2920	2980	6490	7140
Neem cake/urea	3570	4190	3050	3480	6620	7670
ST urea	3930	5080	3360	3500	7390	8550

Chakravorti (1079) observed that the efficiency of ammonium sulphate increased when it was blended with neem cake. The efficiency of a combined application of urea and compost also increased significantly if neem cake was added (Table 84).

Table 84 Effect of different nitrogen sources on yield and nitrogen uptake of rice (Chakravorti, 1979)

N source	Grain yield (g/pot)		Total uptake of N (grain + straw) mg/pot
	Grain	Straw	
Control	2.66	4.41	44.95
Neem cake	3.16	5.14	54.56
Urea	4.73	10.51	109.32
Ammonium sulphate	5.86	11.52	107.49
Urea + cake	6.02	12.22	107.93
A.S. + neem cake	7.27	16.37	149.54
Urea + FYM	5.15	13.81	119.54
A.S. + FYM	5.39	12.56	135.32
Urea + cake + FYM	10.45	14.92	193.33
A.S. + cake + FYM	6.91	11.40	128.10
Lac coated urea	6.77	12.11	123.13

Sharma *et al* (1980) observed that the recovery of nitrogen from urea mixed withneem cake (3:1) was forty three percent as compared to twenty five percent recovery by a potato crop when used as mineral fertilizer alone

4.5 Green Manuring

Meelu and Singh (1978) reported that the yields of wheat and sugarcane increased considerably with green manuring. Sugarcane gave more yield with cowpea than with other green manures (Table 85).

Table 85 Effect of different green manures upon yield of wheat and sugarcane (Meelu and Singh, 1978)

Treatment	Yield kg/ha	
	Wheat	Sugarcane
Control	1280	50 100
Sunhemp	1640	60 700
Dhaincha	1670	57 400
Guar	1530	58 200
Cowpea	-	62 200

Other data given by Meelu and Singh (1978a) indicate that savings of up to 75 kg/ha nitrogen can be made by use of cowpea as green manure (Table 86).

Table 86 Nitrogen economy in a maize-wheat rotation with different green manure crops

N kg/ha	Maize kg/ha				Wheat kg/ha			
	Fallow	Guar	Dhaincha	Cowpea	Fallow	Guar	Dhaincha	Cowpea
50	2190	2440	220	2620	4530	4680	4810	4850
75	2270	2690	2510	3170	4620	4850	4970	5010
100	2430	3130	2900	3390	4590	4910	4990	5150
125	2530	3330	3160	3620	4530	5030	5130	5170

Tiwari *et al* (1980) also found that a considerable economy could be made in a rice - wheat rotation by green manuring (Table 87).

Table 87 Nitrogen economy in a rice-wheat rotation with green manuring

N kg/ha	Rice kg/ha		Residual effect on wheat kg/ha	
	Fallow	Green manure	Fallow	Green manure
0	2370	3850	1670	2310
40	4040	4910	1710	2780
60	4630	5270	1880	3180
120	4980	5370	2270	3350
Mean	4010	4850	1880	2900

In a similar manner, using the green manure Dhaincha, Meelu *et al*(1978) obtained an economy in nitrogen of up to 120 kg/ha. Meelu and Rekhi (1981) observed that the combined use of green manure and 60 kg/ha of mineral nitrogen gave rice yields equivalent to those obtained using 120 kg/ha nitrogen. Meelu *et al* (1977-78) reported that phosphorus added as well as green manure enhances the beneficial effects of the latter (Table 88).

Table 88 Effect of phosphorus on the green matter yield of a green manure and the following rice crop

Treatment	Yield kg/ha Green matter	Rice
26.4 kg/ha P on paddy	15 200	3440
26.4 kg/ha P on Dhaincha	19 500	4240

The phosphorus applied to the green manure increased the yield of green matter, resulted in more nitrogen and higher yield of following crops.

In Table 89 is given the results of an experiment on a reddish-brown earth soil comparing the application of cattle manure and sunhemp at various levels of added mineral nitrogen. Adequate amounts of potassium and phosphorus were given to all plots.

Table 89 Effects of cattle manure and sunhemp on the yield of chillies at different levels of mineral nitrogen

Nitrogen added kg/ha	Yield of ripe chillies kg/ha		
	No organic matter	Cattle manure 25 000 kg/ha	Sunhemp
0	690	470	590
44	680	860	930
88	890	1310	1220
132	1050	1450	1570
176	1190	1160	1480
220	1010	1440	1240

The yield data show the beneficial effects of both green manure and cattle manure. The yield obtained with the high dressing of 132 kg/ha nitrogen in organic matter treated plots could not be obtained by adding more mineral nitrogen in the control plots.

In a field experiment with rice at Yala in 1974, the effect of adding *Glyricidia maculata* and *Tithonia diversifolia* with and without mineral fertilizers was examined (Table 90). The grain yield data indicate that application of mineral fertilizer can be reduced if it is applied together with green manure. Thus, 9 000 kg/ha of green manure in combination with

59 kg/ha of NPK (Fertilizer 2) gave slightly more yield than 106.8 and 126.3 kg/ha applications of NPK at Polonnaruwa and Gampola respectively.

Table 90 Response of rice to application of mineral fertilizer with and without green manure (Amarasiri, 1978)

Treatment	Grain Yield kg/ha	
	Polonnaruwa (dry zone)	Gampola (wet zone)
Control - no fertilizer	3800	4300
Green manure, 4500 kg/ha	3900	4500
Green manure, 9000 kg/ha	4600	4600
Fertilizer-1	4000	4800
Fertilizer-1 + green manure, 4500 kg/ha	4100	5100
Fertilizer-1 + green manure, 9000 kg/ha	4400	5200
Fertilizer-2	4400	4900
Fertilizer-2 + green manure, 4500 kg/ha	5000	5300
Fertilizer-2 + green manure, 9000 kg/ha	6400	5600
Recommended fertilizer	6100	5400
Rice variety	BG 348	BG 1111
Green manure	*Glyricidia maculata*	*Tithonia diversifolia*

Fertilizer-1 NPK at 20.0:5.3:4.2
Fertilizer-2 NPK at 40.0:10.6:8.6
Recommended fertilizer: Polonnaruwa NPK at 69.0:19.8:18.3
Gampola NPK at 81.8:12.5:32.0

In some parts of Nepal, use of plants such as *Artemesia vulgaris* (Titepati), *Euparotium adenophorum* (Banmara) to fertilize paddy fields when flooded is a popular practice. However the use of the green manures with mineral fertilizers gives better results (Karki and Baral, 1978).

Table 91 Effect of Titepati green manure on rice yield

Treatment	Av.yield of grain (g/pot)	Increment over control %	Straw yield (g/pot)	No.of tillers per plant
Control	10.44	-	88.40	6.5
Titepati(100kg/ha N)	14.57	39	116.60	13.0
NPK (100:60:40)	16.73	59	128.70	13.6
Titepati + NPK	19.04	81	484.07	16.4

4.6 Biogas digester effluents

During the aerobic composting of organic materials a loss of some plant nutrients is unavoidable due to volatilization and leaching. If anaerobic digestion is used instead of aerobic composting such losses are considerably less. Furthermore, anaerobically produced 'compost' is in a better physical condition; when dried it is finely divided and more easily incorporated in the soil than conventional compost. From the sanitation point of view too, anaerobic digestion is preferable as flies and their maggots and other insects do not survive.

In China particularly, experiments have been made to investigate the effects of biogas digester effluents upon soils and to compare the fertilizer value with that of aerobic composts. Some results are given in Tables 92 and 93.

Table 92 Effect of biogas digester effluent upon the physical and chemical properties of a soil (Inst.for Soil and Fert.Res.,Sichuan).

Treatment	pH	% O.M.	% Total N	% Total P	B.D. g cm^{-3}	% Porosity
Control	6.9	1.04	0.067	0.042	1.44	45.7
Effluent	6.8	1.21	0.068	0.048	1.41	46.6

Table 93 Response of crops to biogas digester effluent and compost when applied at identical dry weight rates (Inst.Soil Fert.Res.Sichuan).

Crop	Yield in kg/ha	
	Compost	Effluent
Rice	5139	5473
Maize	4389	4780
Wheat	3358	3870
Cotton	1148	1329
Rape	2009	2222

In India field trials have shown that biogas digester effluent is superior to farmyard manure when added at rates equivalent to the same amount of cattle dung used to prepare the two materials. Similar results have been reported in the Philippines.

Digested organic material from a biogas digester can be in three different forms depending upon the design of the digester. In the fixed dome design of digester the manure is available in two forms; effluent which comes out daily and which can be removed from the outlet chamber and, sludge which settles at the bottom of the digester and is available only when the digester is cleaned - normal two times a year. In the floating tank design of digester, which is fed daily

with a mixture of animal dung and water, the manure is obtained as a slurry which comes out daily from the outlet. The use of the manure depends partly upon its form, partly upon whether or not it is stored before use and partly upon the farm management system. For example, the sludge can be used directly just like compost and in this case nitrogen loss is minimal; however, the ammonium content may be too high for crop safety and it may be best to keep the material for a while before use. The more liquid effluents can be sprayed directly onto the fields or they may be used to assist the aerobic composting of new organic wastes. The subject of using biogas digester effluents is discussed in more detail in the project's Field Document No.10 on Biogas Development in Asia.

Not many experiments have been reported on the relative merits of biogas digester effluents and mineral fertilizers and this is a field where more research is needed. However, it can be assumed that as in the case of other organic manures, complementary use will be best although different quantities and proportions may be involved.

The composition of the biogas digester effluents is governed by the composition of the original organic material digested and with the degree of decomposition. An experiment with oats has shown that application of dried effluent at 2.5 ton per hectare was equivalent to an application of mineral nitrogen at 40 kg per hectare (Table 94).

Table 94 Effect upon yield of oats of mineral nitrogen and biogas digester effluent (National Dairy Inst., Karnal, India).

Treatment	Yield of oat fodder (ton/ha)
Control	27.26
N_{20}	28.26
N_{40}	29.51
Biogas digester slurry	31.15
Biogas digester slurry, dried at 2.5 t/ha	29.21

4.7 Salt affected soils

Very good results have been obtained with the combined use of mineral fertilizers and soil amendments together with organic manures for the reclamation of salt affected soils. Yadav (1979) obtained significantly higher yields of berseem and paddy grown in succession on a soil treated with farmyard manure and gypsum than if either treatment was given alone. The solubility of the gypsum was reported to have increased from 31 to 39 m.e. per litre after one month due to farmyard manure (Mondal, 1972,1975). The role of the organic matter in increasing the solubility of gypsum is not precised but the solubility of gypsum is affected by several factors such as temperature, particle size and the presence of other soluble salts. However, it must be remebered that if salts having a common ion with gypsum (i.e. sulphates or calcium) are added, the solubility of gypsum will be decreased.

Application of molasses, press mud and cane leaf at the rate of 25 000 kg/ha together with bonemeal at 100 kg/ha was found to have a very favourable effect on the reclamation of saline soils in Rajasthan, India (Dhar and Singh, 1963).

Raychaudhury (1977) reported that phosphatic fertilizers give better results in saline soils when used in conjunction with green manures. Dargan *et al* (1976) reported the effects of gypsum, farmyard manure and zinc on the yield of berseem, rice and maize grown in a highly sodic soil (Table 95). A significant increase in yield was obtained and there was a high degree of interaction between the manure, gypsum and zinc.

Table 95 Fodder yield of berseem as affected by gypsum and farmyard manure on a sodic soil (Dargan, 1976)

FYM kg/ha	Gypsum kg/ha 0	11 000	Mean
0	150	9490	4820
25 000	830	24480	15150
50 000	1740	31890	16810
Mean	910	26320	

4.8 Exchange capacity of plant roots

Cation concentration in the external solution surrounding the plant root surface affects the cations adsorbed by the surface exchange sites on the roots. Singh and Ram (1976) observed that NPK fertilizers with organic matter increased the root cation exchange capacities for rice and wheat throughout their physiological growth stages. Organic matter and nitrogen, when used separately also increased root exchange capacity but phosphorus and

potassium had little effect. Similar observations were made by Mehrotra and Saksena (1970, Table 96).

Table 96 Cation exchange capacity of wheat roots in a long term permanent manurial trial.

Treatment	C.E.C. of root material 45 days me/100g	79 days me/100g	Yield of whole plant. kg/ha
Control	8.77	8.17	2 079
Ammonium sulphate, 40 kg/ha N	10.97	9.16	2 133
FYM, 40 kg/ha N	11.36	10.14	2 583
Castor cake, 40 kg/ha N	11.47	10.36	2 731
Amm.sulphate + FYM	11.18	10.00	2 106
FYM + superphosphate, $N_{40}P_{40}$	12.13	10.38	2 898
Amm.sulphate + Superphosphate $N_{40}P_{40}$	12.14	11.15	2 988
Amm.sulphate N_{20} + FYM, N_{20} + superphosphate P_{40}	12.55	12.35	3 065

4.9 Sewage farming and use of fertilizers

Shende and Sundaresan (1978) reported that the combined use of sewage and mineral fertilizers gave increased yield of crops. The results for wheat averaged for a period of seven years are given in Table 97

Table 97 Effect of undiluted and diluted sewage irrigation with and without nutrient fortification on the yield of wheat grain (average of seven years)

Dilution of sewage	Yield of wheat grain kg/ha No fertilizer	Recommended NPK	Supplemental NPK
Undiluted, raw	2228	2853	2947
Diluted, 1:0.5	2171	2885	3025
Diluted, 1:1	2135	2955	3035
Diluted, 1:2	1873	2963	3287
Well water	1421	2624	-

4.10 Use of Azolla and alga in conjunction with mineral fertilizers

Considerable attention is now being paid to the use of 'biofertilizers' as a source of nitrogen for crops. The effect on crop yield when biofertilizers are used separately and in conjunction with mineral fertilizers has been studied; Goyal (1978) reported the results obtained through algal inoculation at different levels of nitrogen and showed that combined application of algae and nitrogen was better than the corresponding level of nitrogen alone (Table 98).

Table 98 Grain yield of rice (IR8) due to algal inoculation at different levels of mineral nitrogen fertilization (pot culture experiments, average of six replicates) Goyal, 1978.

Treatment	1967 grain yield g	1968 grain yield g
Control	3.96	2.16
Algae	5.83	4.40
20 kg/ha N	6.90	4.45
40 kg/ha N	10.31	7.68
60 kg/ha N	13.55	11.58
80 kg/ha N	14.40	14.20
100 kg/ha N	13.86	14.88
20 kg/ha N + algae	7.30	7.26
40 kg/ha N + algae	10.58	9.26
60 kg/ha N + algae	16.15	13.40
80 kg/ha N + algae	18.03	14.55
100 kg/ha N + algae	24.88	19.55

Srinivasan and Ponnayya (1978) showed that at all levels of nitrogen tried, algal application to paddy soils resulted in enhanced grain yield. The results of some experiments are summarised in Tables 99 and 100.

Table 99 Effect of algae and mineral fertilizer upon yield of rice in adaptive trials

Treatment (kg/ha)			Mean yield (kg/ha)		
N	P	K	Vellore (11 trials)	Trichy (8 trials)	Cudalore (10 trials)
50	25	25	4235	4557	3789
50	25	25 + algae	4455	4785	3884
75	37.5	37.5	4400	4485	3953
75	37.5	37.5 + algae	4565	5117	4156

Table 100 Effect of mineral fertilizer and algae upon rice yield

Treatment (kg/ha)			Grain yield (kg/ha)	
N	P	K	Adt.31	IR-20
0	22	41.5	4175	4106
0	22	41.5 + algae	4650	4715
25	22	41.5	4675	4814
25	22	41.5 + algae	5025	5518
50	22	41.5	4900	5611
50	22	41.5 + algae	5200	6380
75	22	41.5	5150	6311
75	22	41.5 + algae	5550	7091
100	22	41.5	5575	6948
100	22	41.5 + algae	6000	7819

In Table 101 the results are given of a replicated field experiment with rice in Lanka. The field was inoculated with Azolla three weeks before transplanting followed by a second inoculation one week after transplanting. The plots treated with Azolla gave yields comparable to those obtained by fertilizing with 88 kg/ha of nitrogen.

Table 101 Effect of Azolla on yield of rice (Amarasiri, 1978)

Treatment	Grain yield index
Control	100
Azolla alone	132
N P K Mo	195
P K Mo and Azolla	232

The mineral nitrogen was added as urea to 88 kg/ha N.

Pande (1978) reported the results of combined use of Azolla and mineral nitrogen fertilizer on yield of paddy; the combined use gave better results than separate use (Tables 102 and 103).

Table 102 Effect of Azolla and mineral nitrogen on yield of paddy (Pande 1978)

Treatment	Kharif 1976 (CR1005)				Rabi 1977 (Kalinga-2)			
	Grain		Straw		Grain		Straw	
	kg/ha	% increase	kg/ha	% increase	kg/ha	% increase	kg/ha	% increase
Control	4875	-	4925	-	1722	-	1325	-
Azolla 10 000-12 000 kg/ha fresh	5316	9	4175	25	2423	41	2087	58
Azolla 20 000 - 24 000 kg/ha fresh	5605	15	6650	35	2623	53	2587	95
Unincorporated Azolla 10 000-12 000 kg/ha	5158	6	5800	18	2400	39	2025	53
20 kg/ha N basal	5173	6	5900	20	2208	28	2100	58
40 kg/ha N basal	5483	13	6725	37	3187	85	3437	159
60 kg/ha N basal	5819	19	6750	37	3518	104	3737	182
80 kg/ha N basal	6082	25	6800	38	3894	126	4650	251
30 kg/ha N + Azolla 10 000 - 12 000 kg/ha	5664	16	6400	30	3461	101	2837	114
50 kg/ha N + Azolla 10 000 - 12 000 kg/ha	6363	31	7750	57	3576	108	3032	129

Table 103 Use of Azolla as a top-dressing (incorporated after one month from Planting) Pande, 1978

	Grain yield		Straw yield	
	kg/ha	% increase	kg/ha	% increase
Control	3937	-	4233	-
Azolla, basal, 10 000 kg/ha	4737	20	4667	10
Azolla, basal, 5 000 kg/ha (unincorporated)	4120	5	4667	10
Azolla, basal, 10 000 kg/ha (unincorporated)	5183	32	5200	23
Azolla, top dressing 5 000 kg/ha, inc.	4440	13	4250	0
Azolla, top dressing 10 000 kg/ha, inc.	4557	16	4200	0
Azolla, top dressing, 15 000 kg/ha inc.	5230	33	5600	32
Ammonium sulphate 30 kg/ha N	5670	44	6000	42

APPENDIX 1

GLOSSARY

Arhar - *Cajanus cajan*

Bajra - *Pennisetum typhoides*

Jowar - *Sorghum vulgare*

Ragi - *Eleusine coracana*

Neem cake - Oil cake resulting from extraction of *Azadrichta indica* seeds

Rape cake - Oil cake resulting from extraction of *Brassica campestris* seeds

Guar - *Cyamopsis psoralioides*

Dhaincha - *Sesbania aculeata*

Sun hemp - *Crotolaria juncea*

Berseem - *Trifolium alexandrinum*

Kharif - Rainy cropping season (June-July to Sept.-Oct.)

Rabi - Winter cropping season (Oct.-Nov. to March-April)

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